# The Engineer

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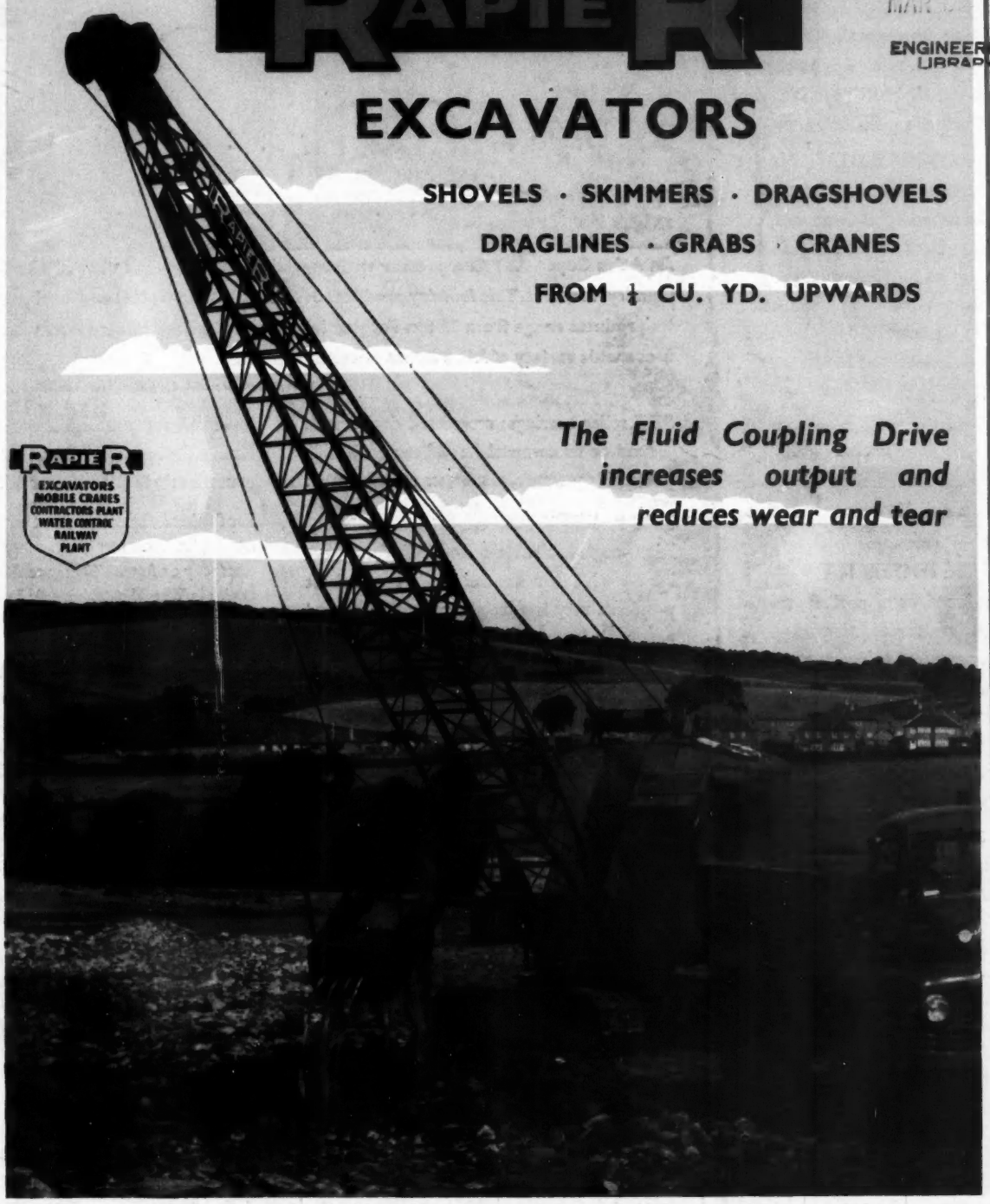


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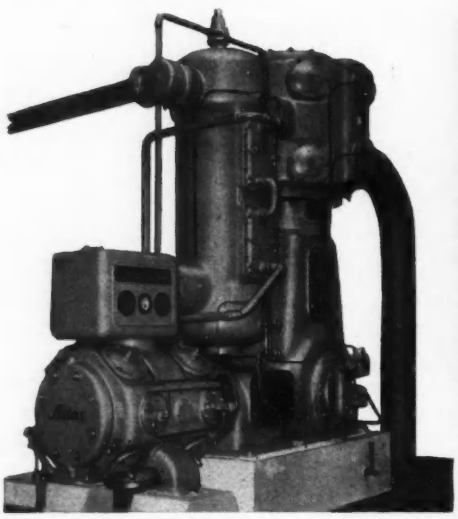

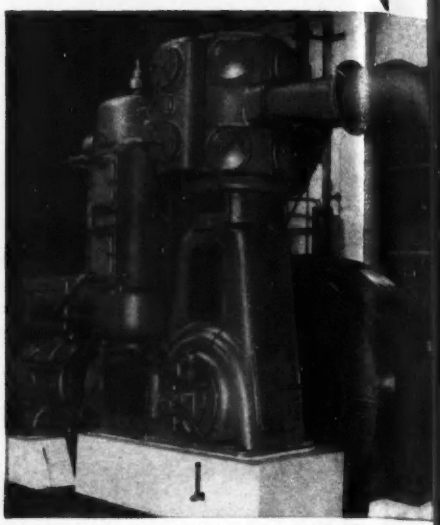

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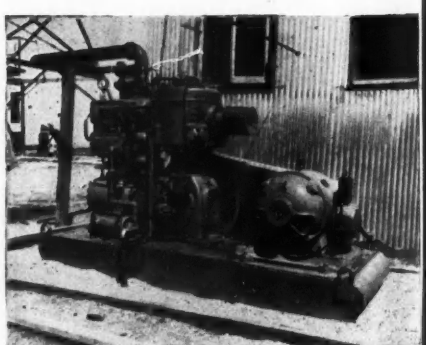
The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world.

For further information about the equipment featured please contact your nearest Atlas Copco Company or Agent. There are Atlas Copco companies in Wembley (England); Paris; Rotterdam; Milan; Brussels; Copenhagen; Oslo; Stockholm; Essen; Madrid; Istanbul; Nicosia (Cyprus); Casablanca; Benoni (Transvaal, S.A.); Ndola (N. Rhodesia) and Bulawayo (S. Rhodesia); Montreal; Paterson N.J. and San Carlos Cal. (U.S.A.); Torreon (Mexico); Auburn (N.S.W. Australia); Wellington; Rio de Janeiro; Santiago de Chile; Lima. If you have difficulty in contacting your local Atlas Copco organisation please write to Atlas Copco AB, Stockholm 1.

PERFORMANCE FIGURES OF ATLAS COPCO AR COMPRESSORS

| Type | Maximum pressure lb./sq. in. | Speed at 50 cycles r.p.m. | Low-pressure piston displacement cu. ft./min. | Free air delivery at 100 lbs./sq. in. cu. ft./min. | Power required at 100 lbs./sq. in. h.p. | Cooling water required at 60° F approx. gal /hr. | Weight lbs. |
|---|---|---|---|---|---|---|---|
| AR 1 | 120 | 600 | 400 | 330 | 62 | 310 | 3000 |
| AR 3 | 120 | 500 | 715 | 570 | 105 | 500 | 5400 |
| AR 4 | 120 | 429 | 910 | 760 | 138 | 680 | 6600 |
| AR 5 | 120 | 375 | 1235 | 1000 | 186 | 880 | 9000 |
| AR 7 | 120 | 333 | 2120 | 1740 | 318 | 1520 | 14500 |
| AR 9 | 120 | 300 | 4020 | 3210 | 586 | 2920 | 26400 |



**A skid-mounted Atlas Copco AR Compressor in operation at Pima Mining Co., Arizona, U.S.A.**

**Atlas Copco**

*Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment.*

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# THE ENGINEER

VOL. 203 No. 5275 MARCH 1, 1957

CONTENTS

LEADING ARTICLES—
Russian Education for Engineers... ... 317
Research in Nuclear Science... ... ... 318

ARTICLES—
Aluminium Alloy Fishing Boat. (Illus.) 345
Annual Report of the Chamber of Shipping ... ... ... ... ... ... 319
Articulated - Steel - Plate Conveyor. (Illus.) ... ... ... ... ... ... 345
Automatic Position Plotting. (Illus.)... 344
Drip-proof Squirrel-Cage Motors with Class-E Insulation. (Illus.)... ... 343
Effect of Interrupted Loading on Mechanical Properties of Metals. No. II. (Illus.) ... ... ... ... 325
Electrical and Allied Plant ... ... ... 335
Electrification of the Severn Tunnel Pumping Stations ... ... ... ... 319
Engineering Education in the Soviet Union ... ... ... ... ... ... 340
Engineering Problems in the Application of Nuclear Energy. No. II. (Illus.) ... ... ... ... ... ... 320
Festival of Industrial Films ... ... ... 319
Hydraulic Buffers for Railway Stock. (Illus.) ... ... ... ... ... ... 344
Large Mechanised Foundry and New Machine Shop... ... ... ... ... 343
Mechanical Engineers and Clean Air (Illus.) ... ... ... ... ... ... 328
Mechanical Strength of Power Transformers in Service. (Illus.) ... ... 331
Prestressed Concrete Runways ... ... 319
Scientific Investigation of the Upper Atmosphere ... ... ... ... ... 342
Ships Launched in 1956... ... ... ... 319
Toll Roads in the U.S.A. No. II... ... 323
100 Years Ago... ... ... ... ... ... 318

METALLURGICAL TOPICS—
Low-Alloy Steels. (Illus.) ... ... ... 336
Centenary of the Regenerative Furnace 337
Austenitic Chromium-Manganese Steel Containing Nitrogen ... ... ... 337
Molybdenum ... ... ... ... ... ... 337

CONTINENTAL SECTION—
Solid Wheel and Disc Mill. (Illus.) ... 347
Rourkela Steel Works ... ... ... ... 347
European Coal and Steel Community Production in 1956... ... ... ... 348
Surface Finish Measuring Instrument. (Illus.) ... ... ... ... ... ... 348

AMERICAN SECTION—
Drought in the Great Plains... ... ... 349
Dedication of Historic Steam Turbo-Generator. (Illus.)... ... ... ... 349
Construction of 100,000-ton Tanker ... 349
Continuous Casting Machine for Non-Ferrous Metals. (Illus.) ... ... 350
Twenty-High Cluster Mill for Rolling Ultra-Thin Strip. (Illus.) ... ... 351
Hydraulic Contour Tracing Attachment for Turret Lathes. (Illus.) ... ... 351

LETTERS AND LITERATURE ... ... ... ... 338

LETTERS TO THE EDITOR—
Floating Stations for Nuclear Power Plants ... ... ... ... 338

LITERATURE ... ... ... ... ... ... 338

NEWS AND NOTES—
Advanced Engineering Courses ... ... 354
British Patent Specifications. (Illus.)... 353
British Standards Institution... ... ... 334
Forthcoming Engagements ... ... ... 354
Industrial and Labour Notes... ... ... 346
Personal and Business ... ... ... ... 352
Technical Reports ... ... ... ... ... 339

## RUSSIAN EDUCATION FOR ENGINEERS

The team sent out by the Institutions of Civil, Mechanical and Electrical Engineers to study engineering education in Russia is very heartily to be thanked for its report. The team spent only a little more than a week in Moscow and Leningrad and we doubt whether it has really added very much to what was already known or thought about the subject. But it has made the foundation sound. What was formerly some visitor's impression; what appeared possibly to be merely Soviet "propaganda" has been placed upon a firmer footing. It is true, of course, that the report as a whole is based upon what the team was told by the Russians; but it is also true that nothing that the team saw nor any of its members' discussions with Russian educationalists conflicted with what the Russians said. The document, in so far as it relates to what the Russians are doing, can be taken as factual and true.

It emerges from the document—part of which is printed elsewhere in this issue—that the system of technological education in Russia is very similar to that ruling over the Continent of Europe as a whole. There is the same tendency to concentrate engineering education into technological colleges rather than to make it a university subject; there is the same tendency for academic courses to be of longer duration than in this country; there is the same tendency towards strong specialisation in the last year or two of the course; and there is the same trend towards educating the young man to be immediately useful industrially as soon as he graduates from the college. Starting at a younger age by some eighteen months than his British counterpart, the Soviet student at a technological institute experiences about double the number of hours of instruction and graduates about a year later. But whereas the major proportion of engineering graduates in this country go on to a two-year period of works training, the Russian youngsters go directly into industry. There will, no doubt, be argument as to which is the better method of training engineers: but we confess we find it rather fruitless. That argument was begun long before the war and has gone on ever since. Certainly the continental system has merits. One of those merits is that it draws industry and the colleges of technology close together. For, because the last two years of a continental engineering course tend to be specialised and to be designed to make a student immediately useful to industry, part time lecturers from industry have to be drawn in and much sponsored research is done at the colleges. Yet the British system—more particularly where industrial firms have consciously planned courses of works training for graduates—has its merits, too. There is still a great deal of art and craft in engineering, there are still limits to the practicable; and to have worked with and amongst men is of great advantage when the time comes to direct them. Moreover, it is surely sound to leave a choice of specialisation until some better conception of what it really means industrially has been gained by works experience than to choose at college.

But in our view the force of the report will be lost if too much attention is given to what is in fact really detail. The truth probably is that every country adopts an educational system and amends and changes it to accord with its economic circumstances. In Russia, where one five-year plan follows another and the whole economy is centralised, the need for a given number of specialists in a given field can be foreseen some years ahead; but in ours, much more free, and serving markets where demands change unpredictably, it cannot. One cannot closely compare educational systems designed to meet such wholly differing economies. The really valid comparison lies in the numbers trained. For one would suppose that in the more free and flexible economy, depending for its livelihood upon its ability to be a jump ahead of its competitors, there should be a higher proportion of fully-trained technologists. Yet in fact the Russians are training three times as many engineers per head of the population as we are and, at least roughly, to the same standards! It may, of course, be claimed that a reason for this remarkable educational effort is the fact that Russia is making a determined effort to catch up upon the relatively high living standards of Western Europe and the U.S.A. But there is further cause for surprise. The Government of this country would undoubtedly be willing to expend more of the nation's income upon expanding facilities for technological education than it has already planned to do. The limiting factor is not expense; it lies in the number of youngsters who can reasonably be expected to adopt a technology as a career. Why is it that in Russia engineer-

ing as a career seems to youngsters so very much more attractive than other professions that, proportionally, three times as many as here adopt it? We doubt whether the explanation is wholly to be found in scales of pay and certain privileges granted to engineers or in the exceptionally good financial remuneration of those who take up teaching. More probably, throughout the country, there is a much higher appreciation than there is here of the value of an engineer's work. The lesson to be learned from the report is, in fact, much the same lesson as is to be learned from visits to America. If this nation is to remain in the van of technological progress and is not gradually to fall back into a second-class impoverished and backward country its engineers must gain heightened prestige and an improved status in the understanding of its people as a whole. It is gratifying to note that smaller societies besides the major engineering institutions are, perhaps rather unconsciously, setting their hands to this task. For the shortage of technologists in industry has caused the institutions to give increasing attention to the need to attract boys at school and to educate masters to a better understanding of the cultural and intellectual content of a career in engineering.

### RESEARCH IN NUCLEAR SCIENCE

It has been evident for some time that nuclear research in British universities has been tending to lag behind that of their counterparts in the United States. In America it is the scientists in universities such as California that are setting the pace in experimental work designed to extend fundamental knowledge about matter and the atomic nucleus. That this has not been the case in this country is due, not to any lack of interest in the subject by our own scientists, but to a reason all too familiar these days; the need for large sums of money to support such work. In this field we have passed out of the stage when an experimental physicist with the aid of a few laboratory technicians could design and build his own apparatus, and with it make some major contribution to basic knowledge. To-day the nuclear scientist requires a source of high energy particles or a high neutron flux as well as the apparatus, probably expensive apparatus, for his own experiment. The machines or the nuclear reactors that can give him the particles or flux are no longer pieces of laboratory equipment but major items of capital plant. In the United States, several of the principal universities already have their own research reactors, and some, such as the University of Michigan, are in the fortunate position of being able to pursue a broad programme of nuclear research backed by substantial funds. Although it is now possible to design and build a large variety of low-power research reactors comparatively cheaply, they are not the machines that are wanted. They can only give a fairly low neutron flux and so can only serve as demonstration and teaching units. For much of the more advanced work, reactors working at high neutron fluxes and high powers are necessary. For this class of machine

## The Engineer
### 100 Years Ago
(FEBRUARY 27, 1857)

"OUR COLONIAL LABOUR MARKET"

"Our Governments, home and colonial, have hid their engineering talent in a napkin. What is wanted is a 'back-bone-and-rib-railway pioneering system' on which to base the industrial resources of our immense colonial empire; and the more labour is abridged by machinery and thus subdivided in the mother country, the more imperatively urgent will be the demand of her surplus-population for this pioneering iron-way foundation, on which as a fulcrum successfully to work our colonial Industrial-Machine.

"The effect which the abridgment of labour by machinery in the mother country is having upon the labour-market of our colonies merits the timely consideration of our home and colonial Parliaments, and the most serious investigation of our political contemporaries. We are fast approaching to the period of steam-culture and cartage times, when our country labourers, blacksmiths, carpenters, etc., of the old school, said only to be adapted for our colonies, will no longer be found. Now, such being the prospects at no great distance before us, as every one acquainted with the progress of engineering in our provinces must clearly foresee, we may fairly ask the question at present—what will become of our surplus population when such a period shall arrive, should our present antiquated system of colonisation be continued by Government, and nothing done towards laying the iron-way foundation already brought under notice? What will become of our steam-plough, cart-sowing, and reaping machine engineers in a colony?

"We are annually abridging manual labour by machinery, so that our surplus population is becoming more and more dependent on machine-labour in our colonies, and consequently our colonial labour market is also annually falling more and more into a deranged and depressed state. Now the obvious remedy for this state of things is machine labour in our colonies, and this can only be organised with iron-ways for a fulcrum, and the reclaiming and placing of land and its timber in a saleable state by Government, so as to admit of such machinery being set in motion by emigrants on their arrival in a colony."

£1,000,000 ceases to represent a lavish endowment of funds.

On February 14, Mr. Powell, answering questions in the House of Commons, gave information on the Government's proposals on this subject. He stated that following consultations with the University Grants Committee, the Atomic Energy Authority and the Departments concerned the Government has decided to set up a National Institute for Research in Nuclear Science. The main object is to provide the facilities and equipment for the universities and institutions carrying out research in this field—facilities which would be beyond the means of any individual university to provide. The idea is that such facilities will be additional to, and not in place of, any assistance now being given from Government funds to individual institutions. The Institute will be financed by grants through the Atomic Energy Authority while the universities' expenditure will be confined to the payment of the salaries and expenses of their own academic staff who utilise the research facilities provided. Management will be by a governing board consisting of representatives of the universities, the Atomic Energy Authority, the University Grants Committee, the Royal Society and the Department of Scientific and Industrial Research, with an independent chairman.

The decision to set up the Institute is to be welcomed, as the clarification of the position should now enable developments to go ahead rapidly. In this matter some centralisation of research facilities appears to be inevitable. Any attempt to provide individual universities with machines such as nuclear reactors, would not only have entailed an unreasonable expenditure, but to many it could also have proved a serious embarrassment. The operation and maintenance of some of these facilities requires a large well trained staff, and, for example, high-power research reactors will have to be operated in accordance with strict rules in order to comply with safety regulations. Under the proposed arrangements university departments will not have to worry about the management of these facilities, or about the recruitment and training of operating and maintenance personnel. Instead their staffs will be able to concentrate on the experimental use of the equipment provided. Some difficulties are, however, inevitably introduced. Grouping of facilities will mean that university research staff will be working away from their own departments and the particular characteristics of individual schools may thus tend to be obscured. It is, however, important that methods of using the facilities provided by the Institute be worked out, without destroying the autonomy of the various university departments concerned. It is essential that not only should good use be made of the facilities as a matter of economics, but that the universities should again be in a strong position to make real contributions in the field of basic nuclear research. Although large sums of money are already being spent on nuclear research it must not be forgotten that the major part of this work is designed to obtain the data required for building and operating nuclear reactors. There will always remain a real need for fundamental work unhurried by any considerations of possible applications. It is the universities that are best fitted to carry out this work and the National Institute for Research in Nuclear Science must make it possible.

# A Seven Day Journal

### Electrification of the Severn Tunnel Pumping Stations

THE Western Region of British Railways announces that the steam-driven pumping plant in the Severn Tunnel pumping stations is to be replaced by electrically driven submersible pumps. The steam-driven pumping engines are of the Cornish single-acting design, and some of them are over seventy years old. Under the re-equipment scheme, the twelve steam sets at Sudbrook are to be replaced by twelve submersible pumps, each capable of handling about 200,000 g.p.h., and the two steam sets at Sea Wall by two submersible pumps, each with a capacity of about 120,000 g.p.h. Provision is being made for 100 per cent standby pumping capacity and diesel generator equipment capable of meeting the maximum electrical demands in the event of a failure in the main power supplies. The scheme also envisages the introduction of a central control room for the pumping equipment. It is pointed out that at Sudbrook the quantity of water which has to be pumped varies between 13,500,000 and 22,500,000 gallons a day, most of which comes from one spring known as "Big Spring." In view of the historic interest of the steam plant, arrangements are to be made to preserve in good condition, *in situ*, the cylinders, beams and gear above ground level in No. 1 pump house. Consideration is also being given to the provision of a suitable arrangement which would permit the operation of one of the beams and its gear. The 4 miles 624 yards long Severn Tunnel was passed for service on November 17, 1886, and since that time the steam pumps have never wholly ceased working, having been used in sequence according to the volume of water flowing to them. It is also stated that proposals are in hand to replace the horizontal tandem compound engine driving the tunnel ventilation fan by an electrical drive.

### Annual Report of the Chamber of Shipping

THE annual report for 1956–57 has been published by the Chamber of Shipping of the United Kingdom. It reviews the main events of the year, including the development of the Suez Canal situation, together with the repercussions of its closure upon British shipping. It is emphasised that national prestige or partisanship is no reason for depriving the world of the canal and expresses astonishment at continued political debates while practical shipping problems are completely ignored. Another point made in the report is that the United Nations have not consulted competent authorities upon shipping issues involved in reopening the canal. The Suez Canal closure, the report comments, has clearly demonstrated Britain's dependence upon the Merchant Navy. The clear statement of the Chancellor of the Exchequer, which removed misconceptions about investment and profits, was welcomed by the industry, the report says, and it goes on to state that the 20 per cent investment allowance is inadequate and that there must be increased investment in ships so as to add to our foreign exchange earnings. Comment is made upon the increase in the tonnage registered under flags of convenience and upon the fact that these countries cannot exercise proper control. On the subject of the European Free Trade area the report notes that the effect on merchant and trader will be direct, while the effect on the shipowner, who already operates under circumstances of world free trade, will be indirect and thus not easily predicted. It is recorded that world shipping increased during the year by 4,500,000 tons to a total of 105 million gross tons, of which the British share is 19,500,000 tons, or 189,000 tons more than the previous total. Thus, the comparative increases are, respectively, 4½ per cent and 1 per cent, which means that we are falling behind with a resultant diminution of our capacity to pay for imports of food and raw materials. Concerning the development of nuclear power the report states that the industry is aware of the need for research but believes that the cost is beyond its resources, as suggested by the fact that Government sponsored development of one aero-engine has cost the taxpayer £12,000,000.

### Prestressed Concrete Runways

ON February 25, a talk was given by Monsieur A. Mayer, president of the French cement makers' research organisation, on the construction of the two prestressed concrete runways at Maison Blanche airfield in Algiers. Monsieur Mayer was addressing members of the Prestressed Concrete Develop- Group, and his talk was given in the lecture theatre of the Royal Empire Society, in London. A film showing the constructional work at the airfield was also shown. The runways were constructed in 1954–55 and are considered to have been economically competitive with normal construction, even though the sub-base was not reduced in thickness, as it could well have been, Monsieur Mayer pointed out, for such a design. The concrete slab of the runway is 18cm thick (half the thickness of the corresponding slab without prestressing) and is stressed transversely by twelve-wire Freyssinet cables and longitudinally by flat jacks, with "abutments" built to take the thrust at each end of the runway. The runway is thus built without any joints; it was designed for a working load of 45 tons on a 2ft 6in diameter circle but was tested up to 100 tons without cracking. Recent trends and improvements in this class of construction were briefly described by Monsieur Mayer in his talk. He thought that the problem of building roads in prestressed concrete was much more difficult than that of the airfield runway; nevertheless, such construction was practicable, and was being developed in France. It was hoped, he said, to construct an experimental stretch of prestressed concrete road next summer.

### Festival of Industrial Films

LAST week, the council of the Festival of Films in the Service of Industry held its first meeting, in London, under the chairmanship of Lord Godber. In a statement issued at a conference held after the meeting, details were given of the arrangements for the festival which is to be held at Harrogate from October 8 to 12. Designed to focus attention on the contribution which sponsored films can make to the solution of problems confronting British industry to-day, the aims of the festival, which is the first of its kind to be organised in this country, are stated to be: a wider understanding of what films can do for industry; to show how industry uses films for such purposes as training, productivity, human relations in industry, sales promotion, health and safety, and to improve the quality of industrial films and the way in which they are used. The increasing use of films for industrial purposes has indicated the need for an appraisal of films recently produced, and during the festival a selection of the latest and best industrial films produced in this country will be screened, together with a number from overseas. Sessions will be devoted to talks by experts on the production and use of films in such matters as training and industrial safety, and opportunity for discussion will be given. Awards will be made for the best films in the various categories and the final adjudication will be made by panels of judges representing those who commission, those who make and those who see the films. Awards for this, the first, year will apply only to United Kingdom entries. Categories of films to be shown include "Training Inside Industry," "Technical and Technological," "Films for Use in Schools," "Health and Safety in Industry," "Industrial Productivity," "Guidance on Careers in Industry," and "Human Relations in Industry." The latest date for entering films for this festival is July 1, and application forms may be obtained from the organising secretary, 3, Portman Chambers, 7–9, Baker Street, London, W.1.

### Ships Launched in 1956

LLOYD'S REGISTER OF SHIPPING has published its annual summary of merchant ships launched in the world during 1956. During the year 275 ships of 1,383,387 tons (seventy-one steamships of 734,551 tons and 204 motorships of 648,836 tons) were launched in Great Britain and Northern Ireland, which was 90,550 tons less than in 1955, and 20·7 per cent of the world output compared with 27·7 per cent in the previous year. The total included forty-six oil tankers of 518,126 tons, representing 37·5 per cent of the total output, compared with 648,414 tons and 44 per cent, respectively, in 1955. Of the total launched, seventy-six ships of 434,562 tons, or 31·4 per cent, are for registration abroad, representing a decrease from the 1955 output which was 539,336 tons, or 36·6 per cent. Abroad, 229 steamships of 2,034,639 tons and 1333 motorships of 3,255,675 tons, making a total of 1562 ships of 5,290,314 tons, were launched, representing an increase of 1,447,509 tons over the 1955 output. The leading countries were Japan with 1,746,429 tons, and Germany with 1,000,498 tons, the Japanese total exceeding the British total by 363,042 tons. Oil tankers totalled 187 ships of 1,748,937 tons, which represented 33·1 per cent of all tonnage launched, and compares with 46·5 per cent in 1955. The overall total includes 2,765,178 tons, or 52·3 per cent, which are for registration outside the country where built. Throughout the world the total tonnage launched increased by 1,356,959 tons, compared with 1955, to 6,673,701 tons, of which 26 per cent was built in Japan, 21 per cent in Great Britain and Northern Ireland, and 15 per cent in Germany. Included in the total are 233 oil tankers of 2,267,063 tons, representing 34 per cent of the total, and a decrease of 169,579 tons compared with the previous year, of which 34 per cent were built in Japan and 23 per cent in Great Britain and Northern Ireland. The countries for which the largest amounts of new tonnage have been launched are Liberia with 1,164,593 tons, and Great Britain and Northern Ireland with 1,068,710 tons, while the net export returns are Japan 1,241,820 tons, Germany 620,631 tons, and Great Britain and Northern Ireland 314,677 tons. Of the world total of ships launched, 657 ships of 3,375,736 tons, or 50·6 per cent, were being built under the survey of Lloyd's Register.

# Engineering Problems in the Application of Nuclear Energy

By SIR CLAUDE D. GIBB, K.B.E., D.Sc., M.E., F.R.S.*

No. II—(*Concluded from page 285, February 22*)

*On Friday, February 15, at a meeting of the Institution of Mechanical Engineers, arranged in conjunction with the British Nuclear Energy Conference, the forty-third Thomas Hawksley lecture was delivered. It is reprinted here almost in full. The author first gives consideration to general matters having a bearing upon the design of a nuclear station intended primarily for the generation of base-load power and devotes the major part of the lecture to some of the principles that have influenced the design of the power station to be erected at Bradwell in Essex.*

## Safety

It is now generally accepted that the gas-cooled graphite-moderated reactor does not present any hazard to the general public. Equally important, although not generally appreciated, is the fact that by careful design it can be arranged that the reactor will not suffer serious damage due to the failure of its control or main cooling systems. The prime consideration in this respect is the prevention of excessive fuel temperatures. If at any time the ratio of the heat output to coolant flow exceeds the design value, overheating of the fuel will occur. An increase in this ratio can be due either to an increase in heat output or a decrease in coolant flow. It is essential that under either condition the rise in fuel temperature shall be a minimum.

The most likely cause of increase in reactor power is withdrawal of the control rods. It is very simple to arrange the maximum rate of withdrawal so that maloperation at start-up cannot produce dangerous power surges and the possible rate of rise of power at operating levels made such that, should automatic tripping devices fail, there would be time to make manual correction on receipt of warning given by a number of independent devices.

Reduction of coolant flow due to a failure of the main circulators would cause a more rapid rise in fuel temperature than that due to control rod withdrawal and particular attention must be paid to maintenance of an adequate flow of coolant at all times.

Elaborate systems of protection are provided to ensure immediate reactor shut-down following such incidents as failure of main circulators, excessive gas pressure, excessive fuel temperature, and excessive power level, but when considering the inherent safety of the reactor the reliability of the protection systems cannot be assumed.

The most serious case to be considered is, therefore, coincident failure of the main circulators and the trip circuits. Under this condition the transient temperature rise of the fuel elements depends upon three main factors :

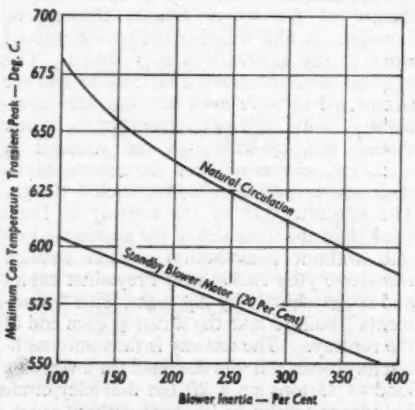
(1) The negative uranium temperature coefficient of reactivity ;

(2) The run down time of the main circulators ;

(3) The capacity of standby coolant plant and the natural circulation inherent in the coolant circuit design.

As soon as the flow of coolant falls the fuel temperature rises, and because of the negative temperature coefficient of the fuel, the power starts to fall. If the rate of change of flow is small enough, the power falls almost in step with it and there is only a slight rise in fuel temperature. However, the collapse of power cannot follow rapid reductions in flow and the rise in temperature can be excessive.

The rate of fall of flow on failure of the main circulator drives can be reduced by increase in the inertia of the main circulators. The effect of this on maximum fuel temperature is shown in Fig. 8. By careful design of the coolant circuit it is possible to achieve a sufficient flow of coolant by natural circulation to remove the heat and keep the fuel element temperature only slightly above the normal operating level when ultimately the circulators come to rest. The provision of auxiliary circulator drives which automatically take over and maintain forced circulation further limit both the maximum and final




Variable blower inertia (normal = 100 per cent)

**Fig. 8—Blowers fail, control rods fail to trip**

fuel temperatures. This is also shown in Fig. 8.

During the transient following circulator failure, the increase in coolant temperature causes increase in coolant pressure which, if great enough, would cause the safety valves to lift. With a suitable run-down time of the main circulators this blow-off can be prevented.

The fracture of a main duct or other portion of the pressure circuit with consequent loss of coolant is a possibility which must be considered in the mechanical design of these components and, particularly with the expansion joints, long time life tests with pressure and temperature cycling are necessary researches to make preparatory to finalising design. Should, however, failure occur, with auxiliary drives to the circulators maintaining them at 20 per cent normal speed, the fuel temperature can be maintained only slightly above the design value with the coolant at atmospheric pressure. With natural circulation, while the temperature rise is considerable, it is still appreciably below the melting point of the fuel cans.

## The Reactor Vessel

In the construction on site of large vessels made from thick plates brittle fracture is a definite hazard, since the danger of this increases with the size of the vessel, the thickness of the plates and the depth of the welds, which, besides increasing the stress due to welding, increases the difficulty of locating defects. Once the vessel has been constructed and stress-relieved the danger of brittle fracture is diminished but not eliminated, since, although the plant operates at a temperature well above the transition temperature of all steels, it is subjected to a pressure test while cold before being charged, it is almost certain to be allowed to cool sometimes during its life and it is known that irradiation raises the transition temperature of the steel.

The danger of brittle fracture in pressure vessels can be reduced by using a low-carbon, high-manganese, aluminium-killed steel with a low transition temperature ; that is, a high notched bar toughness at low temperature. But such steels have poor creep properties at high temperatures. Silicon-killed carbon steel has been used extensively in high-temperature plant and has good stress/temperature properties, but would be likely to fracture on site in cold weather.

One solution is to use a silicon-killed, high-manganese, low-carbon steel and thus obtain the high-temperature properties associated with boiler quality steel suitable for high-temperature service combined with a fairly low transition temperature. Another solution is to obtain, by the addition of alloying elements, a steel with satisfactory stress/temperature properties and a sufficiently low transition temperature. A steel that appears to fulfil those requirements has been developed and is under long-term high-temperature/high-stress testing.

An obvious solution to this difficult problem is to build a double-shell vessel in which a thin inner shell that takes the temperature is made from a suitable steel while a thick outer shell that takes the pressure is kept cool and can therefore be made from an aluminium-killed steel. Like many first solutions in engineering problems, the difficulties increase as detail design develops. The double-skinned reactor vessel becomes less promising when endeavouring to accommodate gas ducts, control rods and charge-discharge standpipes.

Were it possible to increase gas temperatures to the point that austenitic nickel-chromium steel became economic for the pressure vessel, the problem might be simplified, since this steel combines a high resistance to brittle fracture with good mechanical properties at high temperature.

Allowance in design must be made for the corrosion by hot carbon dioxide on the pressure vessels, ducts, circulators, and heat exchangers. Experiments have determined the wastage rates for the different steels used and adequate margins allowed.

*The Cooling Gas.*—Helium and hydrogen are alternatives to carbon dioxide for the coolant. The use of helium would simplify the metallurgical problems, but this gas is expensive and in short supply. The use of hydrogen would, however, intensify the metallurgical problems because uranium reacts with hydrogen to form a hydride of lower density, and hydrogen diffuses readily through many metals at high temperatures, so that it would be difficult to find a canning material which, while suitable in other ways, would prevent hydrogen reaching the uranium and producing a volume expansion that would burst the can.

*Blowers.*—The blowers to circulate the gas can be of the centrifugal or axial type. Mechanical problems, rather than aerodynamic problems, tend to predominate and

* Chairman and Managing Director, C. A. Parsons and Co., Ltd., Newcastle upon Tyne.

Fig. 9—Centrifugal gas blower

the design of blower for a particular project will be influenced mainly by the form of station layout, the requirement for gastight enclosure and any limitations of speed imposed by the type of drive.

On the Calder Hall plant a centrifugal design was selected and the machine is shown in Fig. 9 In general, the optimum speed for a centrifugal blower is much lower than that of the axial, and in this case the design was suitable for the Ward Leonard drive. The large diameter of the impeller, however, introduced a severe problem in obtaining a satisfactory pressure casing and a heavily ribbed structure is required to resist distortion at the sides. The horizontal joint also introduced gas sealing problems because of its size and shape. With regard to station layout, the centrifugal blower, unless mounted vertically, must impose a 90 deg. change of gas flow in the horizontal plane and this is not always desirable when considering duct expansions and general æsthetics.

If the blower drive is suitable for a rotational speed of, say, the order of 3000 r.p.m., then the duty for a gas-cooled reactor can be met by a single-stage axial design. The diameter of the pressure casing can be reduced compared to the centrifugal design, and this enables the impeller to be inserted or withdrawn horizontally to provide a better form of joint in the vertical plane which avoids non-circular shapes. Such an axial blower is shown in Fig. 10. The casing lends itself to fabrication and is designed on normal pressure vessel principles using dished ends. Large flat surfaces are avoided and the resultant increased rigidity of the vessel ensures that flanged joints are not distorted by pressure to produce gas leaks.

To attain a high efficiency with a single stage of axial-flow blading it is necessary to provide an efficient diffuser at exit and to keep the axial velocity of the gas as low as possible. The blower shown in Fig. 10 is arranged with the diffuser coaxial with the shaft to obtain the highest possible efficiency.

The single impeller can be conveniently accommodated on an overhung shaft and only one gas seal is required. A seal suitable for the gas pressures and speeds of these special blowers has been developed from hydrogen-cooled alternator practice. The seal requires oil and the system must be designed to prevent contamination of the gas in the circuits. Present development work is aimed at a gas viscosity plate type of seal which will avoid the use of oil, but much work remains to be done in this direction.

A further possible line of development is the use of gas bearings to enable the complete enclosure of blower and motor in a gastight casing. Apart from the problems present in the design of suitable gas bearings, there are others, such as the cooling of the motor and the possible contamination with active matter which would complicate maintenance.

Although an enclosed design would have advantages from considerations of gas leakage and layout, it is a matter for conjecture whether these advantages would outweigh additional complications. If a suitable gas viscosity seal can be developed then this may prove to be an attractive solution to the problem.

*Blower Drive.*—It is essential that the driving units of the blowers should be reliable and have a high availability in service. Outages for maintenance or faults mean the loss of a complete circuit and an appreciable reduction in output.

Fig. 10—Axial gas blower

The main problem associated with the blower drive is the provision of a variable-speed range. During operation as a base load station the output must be varied between about 70 and 100 per cent full load, and for the highest efficiency the reactor gas outlet temperature should be maintained while the mass flow of gas is reduced by change of blower speed. Apart from retaining good steam conditions by this method, there is an appreciable saving of blower power. At 80 per cent load, for example, the blowing power is reduced to about one-half of the normal requirement and on a large station this may mean a saving of 10MW or 15MW.

Speed variation between about 70 and 100 per cent of normal speed is therefore required on this account, and it is also desirable to have a small overspeed margin to cater for unknowns in the design which might otherwise prevent the guaranteed station output being obtained at design temperatures. In providing such a speed range, it is usually possible to specify a wider range of, say, 5/1 without materially increasing the cost of the equipment. The facility of being able to run the blowers at low speeds or at any desired intermediate value up to full load increases greatly the flexibility of operation, and can help to avoid undue thermal cycling of fuel element temperatures.

The speed variation may be provided in several ways; for example, by variable-frequency or variable-voltage supplies to electric motors, by hydraulic couplings or by direct steam turbine drive. As stressed previously, reliability is the outstanding consideration and a squirrel-cage induction motor, used in conjunction with a variable-frequency supply or, alternatively, a hydraulic coupling, is to be preferred for the blower drive. The variable-frequency drive is superior in having good efficiencies down to quite low speeds, and the power savings at part loads can be shown to justify the extra capital cost of auxiliary turbo-alternators to provide the supply. These auxiliary turbo-alternators reduce the output required from the main machines and therefore ease the turbine exhaust problems on the larger machines.

*Gas Ducts.*—Gas cooling of the reactor requires a number of ducts of large total flow area to transfer the heat output to the boilers even though gas pressures of about 10 atmospheres are used. The main problem in providing the flow area necessary to give

an economic pumping power is to limit the duct diameter to a dimension which will allow the thermal expansion of the pressure vessel, boilers and ducts themselves to be accommodated. The diameter should also be such that severe problems are not introduced into the design and manufacture of gas valves required for isolation and possibly control.

The choice of the number and diameter of the ducts is obviously a problem which is closely related to the problems of the boiler design, and a compromise must be found for both of these plant items, although the number of ducts per reactor and the number of boilers need not necessarily be equal. In general, however, the provision of a number of small ducts for each boiler circuit is not economically desirable and necessitates the control of a large number of valves. One duct per boiler is usually a better solution and the use of restrained bellows units to accommodate the expansion avoids high thrusts on the pressure vessels and boilers.

If the ducting can be arranged so that it lies in one plane, then the bellows units are required to rotate in only that plane and a flexible torque rod mounted inside the unit can replace the external hinge pins normally used (Fig. 11). This type of unit avoids the problems associated with high bearing loads on the hinge pins and also the necessity for ensuring adequate lubrication to reduce friction.

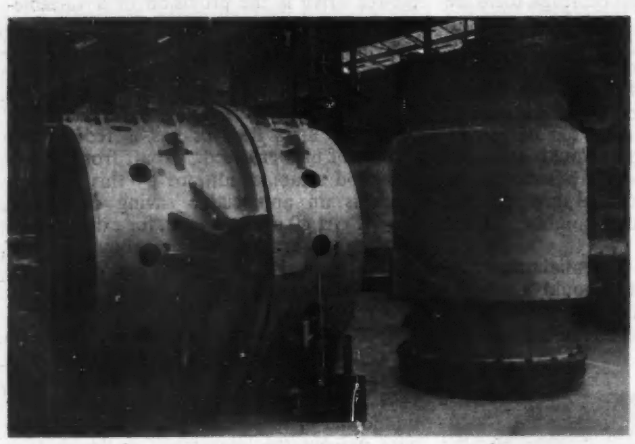


Fig. 11—Single hinged bellows unit

### Steam Cycles and Generating Plant

The gas temperature at outlet from the reactor is restricted to a maximum of about 750 deg. Fah. with magnesium fuel cans, and steam conditions are therefore representative of practice fifteen to twenty years ago. Overall cycle efficiencies with a normal condensing steam cycle would be about 26 per cent, allowing for a reasonable temperature difference between gas and steam in the boilers, but this efficiency has been raised to over 28 per cent by the application of the dual pressure cycle. Consideration has been given to other applications in order to improve upon this efficiency and these include triple-pressure cycles, single pressure with reheat and single pressure with separate superheating from external sources. In general, the dual pressure cycle offers a reasonable compromise between gain in efficiency and complexity and cost, and also offers the advantage that it can facilitate the control of reactor gas temperatures.

In this cycle a quantity of steam is generated at a low pressure, say, about 200 lb per square inch, and the remainder at a much higher pressure, say, 700 lb per square inch. This results in a turbine with two sections with two injection points, the first section being injected with steam from the high-pressure range expanding down to a mixing chamber. At this point steam is injected from the low-pressure range and mixes with the steam from the high-pressure section and finally expands through the second section to a condenser. The choice of high-pressure and low-pressure operating pressures for optimum efficiency is dependent upon the degree of feed heating and the ratio of high-pressure steam quantity to low-pressure steam quantity. The steam pressures at the optimum efficiency produce a high wetness at the turbine exhaust, and because of low temperature there is a large volume flow of steam for a given output in comparison to modern machines. The design of the exhaust is therefore the limitation on unit output, and with two exhausts an output of 50MW to 60MW is achieved at a speed of 3000 r.p.m. compared to 120MW for a plant operating at 1500 lb per square inch and 1050 deg. Fah. The steam wetness and volume flow show little reduction in moving from the optimum efficiency and there is no incentive to lose station output for only a small improvement in these parameters. Consideration has to be given to the use of Stellited blades, water extraction belts and a reduction of blade peripheral velocities in order to obtain a satisfactory design of turbine. The use of three or four exhausts will be necessary to attain unit outputs of 100MW—moderate by present-day standards.

To obtain maximum cycle efficiency it is desirable to raise both the high-pressure and low-pressure steam to the same temperature in the superheater section of the boiler. Large temperature differences are created between the low-pressure steam and the steam in the turbine at the low-pressure injection point, and care has to be taken to avoid problems of differential expansion.

The introduction of two injection points into the turbine presents a problem of control. Also associated with this is the problem of control of the reactor gas inlet temperature. In a nuclear reactor it is advisable to keep thermal stresses in the fuel elements to a minimum and it is to this end that the temperature of the gas at inlet and outlet are kept substantially constant. The inlet gas temperature is controlled by the low-pressure steam pressure in the boiler and, to achieve this, a pressure-control valve is installed in the low-pressure governing system. The high-pressure steam pressure has little effect on the inlet gas temperature and therefore does not require pressure control for normal operation. However, it is not advisable for the high pressure to be allowed to float up or down unchecked as load demands fluctuate, and a definite limit has to be set on this range. Control of the lower limit is achieved by the introduction of a high-pressure unloading device set at a predetermined level which unloads the turbine should the pressure in the line fall below the control setting. The higher limit is controlled by the use of a valve which operates if the pressure in the line increases to above a predetermined setting, allowing the steam to flow into a dump condenser.

Speed governing of the turbine is also essential if the turbine is to have normal frequency regulation. This has to be incorporated in the governing system and it is essential that it does not interfere with the reactor gas inlet temperature control. This necessitates the introduction of two separate governing systems, one for the high-pressure steam, which is used for speed control, and the other for low-pressure steam which is used for pressure control.

### Lifting Facilities

The method of construction of a nuclear power station can strongly influence the overall design and must be considered in the initial planning.

There are two fundamental methods of constructing the large pressure vessel and boilers on the site, and the method adopted is largely dictated by the time available for construction.

If a speedy erection programme is required, and this is generally the case on a large capital contract, then, undoubtedly the best method of construction is to fabricate the large sections of the pressure vessel and complete boiler shells in construction areas away from the reactor buildings. This method of construction gives the minimum of mutual interference and allows the various trades to perform very exacting operations in less confined spaces. In the case of the pressure vessel, this method allows the further use of automatic welding and, in particular, eases the very real difficulties which are encountered in the fabrication of the vessel cap and the charge and standpipe assembly tubes. The boiler shells can also be automatically welded and hydraulically pressure tested in a horizontal position.

The other method is to weld the plates of the pressure vessel and boilers *in situ*. It can be shown, however, that on a large nuclear power station, the construction time will be lengthened.

An economic study of the two methods shows that quite apart from the workmanship aspect of the construction, the saving in time of the former far outweighs the cost of a crane capable of lifting some 200 tons.

Of the four practical ways of lifting the pressure vessel parts and boiler shells into position, a Goliath crane has many advantages. It is estimated that a saving of at least four months can be achieved, due to the high availability of the crane and complete freedom within the erection programme, when compared with its nearest competitor. Furthermore, the Goliath tracks can be extended away from the reactor to cover a marshalling yard which reduces the congestion around the reactor buildings during the civil engineering construction, and, as the Goliath would be designed to span the completed reactor building, a single construction area can serve more than one reactor.

Mention should be made of the nearest competitor to the travelling Goliath, which is the tower-mounted guyed derrick. Undoubtedly its initial cost is lower than the Goliath, but it has the following disadvantages on a large nuclear power station. Due to the limited operating radius of the jib, it is necessary to frequently relocate the tower and the very long guy ropes. A large and specialised labour force is necessary during most of the construction period to carry out the lifting and frequent relocation of the derrick and tower. The necessary guys can also affect the layout of the principal buildings and generally prevent the engineer from

siting the main buildings close together, and in their ideal engineering position.

These disadvantages, together with a longer construction time, when compared with the travelling Goliath, would indicate that the extra capital cost of the Goliath is well justified.

Other types of crane tend to eliminate themselves on capital cost and appear to possess no additional operational advantages.

### Conclusion

From every point of view—economic metallurgical and mechanical—it is essential that the pressure vessels, reactors, ducts, boilers, and circulators should be maintained at as near constant pressure and temperature as possible. In that way, safety and reliability are maintained at the highest level, and this, in turn, leads to the lowest cost per unit of electricity sent out. The whole philosophy of design must be directed to this end. It is a well-established fact that the extent of maintenance on turbo-generators bears a direct relationship to the number of times the units are started and stopped. It is stress and temperature cycling which leads to increased maintenance costs.

The reactor vessels particularly should avoid stress cycling since the irradiation effects on the crown of the shell are thus made of little consequence and no danger.

The boilers will receive oxygen-free condensate feed if the turbo-generators are continuously on load and on the gas side will have relatively pure carbon dioxide. Hence, the amount of maintenance required by the boilers should be negligible.

# Toll Roads in the U.S.A

By H. J. H. STARKS, B.Sc., Ph.D., D.I.C., F.Inst.P.*

No. II—(*Concluded from page 291, February 22*)

*A striking feature of the road developments in the United States of America in the past ten years has been the growth of toll roads. Some aspects of the planning, financing, operation and safety of the toll roads in the eastern States of America are described in this article which is based on information collected by the author during a visit to the United States in 1954–55. The modern toll road is a divided highway with restricted access, having no intersections, sharp curves or steep hills; there are no traffic lights, turning vehicles, pedestrians or cyclists. Like other major highways in America, toll roads are built to the highest engineering standards; the cost of their construction and operation is financed by tolls levied on those who use them. In this respect, toll roads provide one solution of the most pressing problem facing many countries today—the problem of financing new roads. The article gives a brief description of the planning, design, construction and cost of a typical toll road. Data on the usage of toll roads and the problems of traffic diversion and generation are discussed. Information is given on the types of accident occurring on toll roads and on the accident studies which have led to the adoption of various safety measures; in some cases these have greatly reduced the accident rate in spite of a considerable growth in traffic. The number of accidents and the number of personal injuries sustained per million vehicle miles are generally much lower on toll roads than on other main roads. The author's impressions of driving on toll roads under different weather and traffic conditions are also given.*

### Accidents on Toll Roads

MANY of the hazards which exist on other roads are absent on toll roads, but the very absence of these potential dangers, coupled with the good riding qualities and long sight distances, creates other hazards. Speeds are usually higher and are often sustained for comparatively long periods of time, and monotony, fatigue, and lack of driving skill and judgment are important factors which contribute to accidents. Since it is not possible to get on or off a toll road without passing through a toll booth, exact data can be obtained on the vehicle-mileage. Also, a thorough and uniform system of accident reporting can more easily be set up.

From the outset the safety record of toll roads has been an important consideration. An intensive study has been made of accidents occurring on certain turnpikes and steps have been taken which have led to a reduction in the accident rate. The Pennsylvania Turnpike Commission, for example, set up a Joint Safety Research Group to study accident causation; this Group has prepared a report on all the accidents which have occurred on the Pennsylvania Turnpike since its opening.[17] The New Jersey Turnpike Authority has also made a detailed study of accidents and on the basis of the results has taken certain safety measures on the New Jersey Turnpike.

In the Pennsylvania Turnpike report,[17] an analysis is made of 9212 accidents involving 13,426 vehicles which occurred on the Turnpike between its opening in 1940 and the end of 1952. During this period about 57,000,000 vehicles used the road and the total vehicle mileage was 5566 million miles. All accidents are included, whether they involved personal injury or damage only (exceeding 25 dollars). Table IV shows the accident rate per 100 million vehicle miles for the years 1940–1952. The report states that 58 per cent of the accidents occurred during daylight, 36 per cent at night and 6 per cent at dawn or dusk. A survey in 1952 showed that the vehicle mileage during the day was about 50 per cent greater than that at night; this implies that the day and night accident rates per vehicle mile were about the same. Accident rates, in terms of accidents per 100 million vehicle miles, for different conditions of the roadway were as follows: dry, 110; wet, 190; snow and slush, 480; and icy, 820. The nature of the accidents can be seen from the details in Table V.

Table IV—*Accident Rate on Pennsylvania Turnpike, 1940–1952*

| Year | Accident rate per 100 million vehicle miles | Vehicle miles travelled (1940 = 1) |
|---|---|---|
| 1940 | 210 | 1·0 |
| 1941 | 230 | 5·2 |
| 1942 | 245 | 2·8 |
| 1943 | 235 | 1·9 |
| 1944 | 170 | 2·1 |
| 1945 | 135 | 3·1 |
| 1946 | 133 | 5·3 |
| 1947 | 155 | 6·3 |
| 1948 | 155 | 7·5 |
| 1949 | 195 | 8·5 |
| 1950 | 180 | 10·3 |
| 1951 | 160 | 16·8 |
| 1952 | 135 | 24·8 |

Table V—*Nature of Accidents on Pennsylvania Turnpike, 1940–1952*

| Type of accident | Percentage of total accidents | |
|---|---|---|
| | Passenger cars | Commercial vehicles |
| Rear-end collision | 37·5 | 47·6 |
| Collision with object other than vehicle | 13·8 | 7·3 |
| Overturning | 13·5 | 7·6 |
| Median strip | 10·4 | 5·7 |
| Running off roadway (non-collision, non-overturning) | 5·7 | 2·7 |
| Side-swiping | 8·2 | 9·1 |
| Stopping, stopped, parked | 5·3 | 9·5 |
| Fire only | 0·9 | 5·3 |
| Others | 4·7 | 5·2 |

Rear-end collisions accounted for more than one-third of the accidents involving passenger cars and nearly one-half of the accidents involving commercial vehicles.

A special study was made of 1757 accidents which occurred during 1952 and the major factors contributing to each accident are given in the report. In 15 per cent of the accidents the vehicle is reported to have skidded and in another 25 per cent the driver is stated to have lost control; i.e. in 40 per cent of the total accidents skidding or loss of control were said to be the principal or contributory factors. It is reported that, in another analysis of the same accidents, the following items were regarded as the main contributory factor: failure to cope with road conditions (e.g. skidded on icy road, lost control), twenty-two;† illegal or unsafe actions (e.g. pulled out in front of overtaking vehicle, parked in highway), twenty-seven; inattention (e.g. fell asleep, reached for cigarettes on back seat), fourteen; vehicular failures (e.g. tyre blowouts, brake failure), thirteen; deficiencies in routine driving skill (e.g. applied accelerator instead of brake), ten; misjudging distance and rate of closure, five; reduced visibility, three; others, six.

The report lays special emphasis on the environmental factors relating to turnpike accidents. It is concluded that most of the accidents which occurred were primarily the result of driver error in failing to make appropriate modifications in behaviour to cope with the road and traffic conditions. Notwithstanding reductions which might be made in accidents as a result of improvements in vehicle design and maintenance, in road design and in the operation of traffic, the report states that the most promising key to accident reduction lies in better driver education and training.

Accident data obtained on the New Jersey Turnpike are similar to those already described on the Pennsylvania Turnpike. The accident rate per 100 million vehicle miles for personal injury and damage only accidents (damage exceeding 100 dollars) is about sixty, compared with about 400 on other New Jersey State roads. The personal injury accident rate on this turnpike has decreased, in spite of greatly increased traffic over the past three years (1952–1954) from seventy-six to fifty-five per 100 million vehicle miles, and the fatality rate has decreased from 4·1 to 2·6; these rates are lower than those on other New Jersey State roads. The national fatality rate in 1953 was 7·1 per 100 million vehicle miles.[18]

The steady reduction in accident rate on the New Jersey Turnpike has probably resulted from the measures taken to promote safety. In the early stages of operation it was found that many rear-end collisions were occurring, particularly at night, as a result of vehicles running into the rear of vehicles stopping or parked on the shoulders. Pulling off the road was therefore prohibited, except for essential repairs. Many accidents occurred when vehicles ran off the road on to

* Road Research Laboratory, Department of Scientific and Industrial Research.

† The figures denote percentage of total accidents.

the median strip and struck vehicles in the other carriageway or came to grief on the median strip. Shelving of the median strip now makes it more difficult for vehicles to cross completely over it. Vigorous enforcement of the speed limit by police patrols and by using radar speed-meters, a reduction in the maximum speed limit in bad weather and the excellent communication system which enables broken-down vehicles to be removed quickly, have also, no doubt, helped to reduce accidents. Recently, a further reduction in accidents has been brought about by doubling the number of police patrols.

On the older Merritt Parkway the accident rate over the past nine years has been 240 and the fatality rate 3·7 per 100 million vehicle miles. On the adjoining newer Wilbur Cross Parkway the corresponding accident and fatality rates have been 180 and 1·3 per 100 million vehicle miles. A study of the accidents showed that many which occurred on the Merritt Parkway involved a collision with a vehicle stationary on the roadway ; because of the presence of a kerb and also because the grass shoulder was, or appeared to be, soft, most drivers preferred to remain on the roadway to make repairs or to change a wheel. On the Wilbur Cross Parkway, however, vehicles can easily pull off on to the hard shoulder. The new extension to the Wilbur Cross Parkway, having improved design features, has an accident rate (based on the first 60,000,000 vehicle miles) of 150 ; up to 1955 there had been one fatality.

The fact that many accidents occur under ideal conditions, i.e. on a well-designed road, in clear dry weather and with traffic moving at a fairly uniform speed and without many of the usual traffic hazards, perhaps provides an answer to those who declare that the construction of a system of super highways would alone solve the accident problem. Nevertheless, the accident rate and personal injury rates on toll roads are lower, often much lower, than those on other roads.

Attempts are being made to reduce further the accidents which occur on the toll roads. For example, as mentioned earlier, many accidents occur when vehicles leave the road and run on to the median strip. A possible way of preventing vehicles from crossing the median strip and of reducing the likelihood of damage or injury on the strip itself is the use of hedges of certain types of shrub which will absorb the energy of a vehicle which has run off the road. Motor Vehicle Research, Inc., of South Lee, New Hampshire, has conducted experiments by running vehicles into hedges at different speeds and angles of incidence.[19] An evergreen shrub with an interlocking growth, *rosa multiflora japonica*, has yielded promising results. A car travelling at 30 m.p.h. was stopped without damage, except for minor scratches, in about 11ft, corresponding to an average deceleration of 3*g*.

Rear-end collisions are the commonest form of accident on the Pennsylvania Turnpike. On the New Jersey Turnpike, rear-end collisions at night are the commonest type of fatal injury accident. This has raised doubts of the adequacy of existing standards of rear lights, particularly those on commercial vehicles. (The present S.A.E. standard calls for an intensity on the lamp axis of 1·5 cd. for rear lights and 15 cd. for stop lights.) Surveys are being made on these turnpikes of the intensity of rear lights and stop lights on passenger and commercial vehicles, with a view to formulating new requirements and to developing methods of enforcing adequate standards of rear lighting. The results obtained up to 1955[20] showed that the rear lights and stop lights on commercial vehicles appeared inadequate and that there was a need for standardisation of the position of the rear lights on these vehicles.

### Speed of Vehicles on Toll Roads

On all existing toll roads there is a maximum speed limit ranging from 55 to 70 m.p.h. for passenger cars and from 40 to 60 m.p.h. for commercial vehicles. These maximum speeds are strictly enforced. On the New Jersey Turnpike, for example, where the speed limit is 60 m.p.h. for passenger cars and commercial vehicles, over 30,000 drivers were prosecuted for speeding in 1953–54. Of these, 8500 were detected by radar speed-meters. Usually drivers are not stopped unless they are exceeding the speed limit by at least 5 m.p.h. Studies of the speed distribution have been made on several toll roads and the results quoted by the Pennsylvania Turnpike Commission[17] may be cited as representative of the results obtained.

Measurements of the speeds of about 17,000 passenger cars and 9900 commercial vehicles observed in the late winter and early spring of 1953 showed that the median speed of passenger cars on a dry level part of the Turnpike was 56–60 m.p.h. in the 60 m.p.h. speed limit area and 58–64 m.p.h. in the 70 m.p.h. area. Commercial vehicles were observed to travel with median speeds of 46–52 m.p.h. in both the 45 and 50 m.p.h. speed limit areas. When the road surface was wet or when there was light rain the median speed for the passenger cars dropped by about 2 m.p.h., but that of commercial vehicles remained unchanged. On snow-bound, slushy or icy roads the median speed of passenger cars dropped to about 45 m.p.h. and that of commercial vehicles to about 43 m.p.h. There was little increase in the speed of passenger cars on long down grades, but commercial vehicles tended to increase their speed by several miles per hour. A typical set of observations on a dry level section of the 70 m.p.h. speed limit zone showed that 5 per cent of the passenger cars were travelling at more than 70 m.p.h., 40 per cent at more than 60 m.p.h., and 87 per cent at more than 50 m.p.h. On the same section of road, where the speed limit for commercial vehicles was 50 m.p.h., 50 per cent of the commercial vehicles were travelling at more than 50 m.p.h., 20 per cent were travelling at 50 m.p.h., and 10 per cent at less than 45 m.p.h. The results generally indicated that passenger car drivers appear to recognise to a greater extent than do commercial vehicle drivers the hazards of a wet road ; neither class of driver, however, appeared to realise the even greater hazards of slippery road surfaces or of driving at night.

The New Jersey Turnpike is the only toll road in which the maximum speed limit for passenger cars and commercial vehicles is the same. The New Jersey Turnpike Authority, holds the view that, if commercial vehicles are permitted to travel at the prevailing speeds of other vehicles, there will be less chance of rear-end collisions and overtaking accidents.

### Breakdowns

In 1953 the New Jersey Turnpike Authority provided emergency assistance to over 42,000 drivers ; this represented a breakdown or other involuntary stop every 25,000 vehicle miles. The main causes of breakdown were : mechanical failures, 38 per cent ; flat tyres, 22 per cent ; overheating, 21 per cent ; running out of fuel accounted for 8 per cent of stops, and broken fan belts accounted for 2 per cent. On other main roads (toll-free) in New Jersey, including urban roads, a breakdown or other involuntary stop occurs about every 7500 vehicle miles—about three times as frequently as on the Turnpike. On some toll roads, for example on the Pennsylvania Turnpike, there is an accepted form of distress signal if assistance is required ; this is a handkerchief or similar object hung out of the left-hand (driver's) window. Drivers are warned to stay in their vehicle until help arrives. Except for a tool for changing a wheel, most American cars are not provided with tool kits, so that, even in the event of breakdown due to some minor defect or adjustment, the driver is usually unable to make repairs himself.

### Some Impressions of Driving on Toll Roads

After being accustomed to travelling on the narrow, tortuous and congested roads of Britain, the author found it a novel experience to travel on a modern highway as represented by the toll roads described in this article and especially to travel, in company with many other vehicles, at about 60 m.p.h. along the approaches to New York right through some of the most heavily built-up areas in the world.

The author drove an American car on most of the toll roads in the eastern part of the States under different traffic, weather and lighting conditions. On a clear, dry day it was quite easy to maintain a steady speed close to the maximum permissible limit. For example, on the New Jersey Turnpike, the following speeds and journey times were observed on three separate occasions :

| Distance in miles | Time in minutes | Average speed in m.p.h. | Maximum speed in m.p.h. | Minimum speed in m.p.h. |
|---|---|---|---|---|
| 30 | 31 | 58·5 | 62 | 55 |
| 61 | 67 | 55·5 | 60 | 54 |
| 72 | 79 | 54·5 | 58 | 50 |

The smooth, silent motion and the few demands made by the steering wheel gave the author the impression, after driving for a few miles, of sitting in a cinema whilst a film of the road unrolled before him. It was easy to realise how under these conditions drivers might be lulled into a false sense of security and why their reactions in the event of an emergency might be relatively slow. Judgment of speed in the region of 60 m.p.h. to a driver not accustomed to travelling steadily at that speed appeared to diminish with time and the author found it necessary to check his speed on the speedometer at frequent intervals. If other drivers experience the same effect, it is perhaps not surprising that so many of them are prosecuted for exceeding the speed limit. Only two examples of speeding were seen (i.e. speeds of more than about 75 m.p.h.) and one of the drivers was later seen stopped by a police patrol car.

In wet weather, the author noticed that the speed of vehicles was unaffected unless heavy rain was falling. Speeds at night were about the same as by day if the road was dry, but rain caused some reduction ; in the author's opinion, wet-road speeds at night were much too high and headway distances were much too short. In wet weather, the spray thrown up by other vehicles, particularly large commercial vehicles with many (mostly unshielded) wheels, was a nuisance. On some roads, particularly the Pennsylvania Turnpike, with its soil shoulders and embankments, a much greater hazard was encountered after rain

when the road surface was still wet. Spray from other vehicles plastered the windscreens with a muddy film which quickly dried and greatly interfered with, or completely obscured, forward vision. Windscreen washers are not common on American cars and it is, therefore, desirable to make frequent stops to clean the windscreen. Few drivers bother to do this, nor, in some cases, is it safe to do so, and most seem to rely on the windscreen wiper removing the worst of the deposit. Obscuration of the rear and side windows by the deposition of moisture is also frequently seen in many American cars in cold or damp weather.

On several occasions, the author appreciated the value of a toll road in relieving him of the difficulties of route finding and of traffic hazards when travelling through congested areas at night or in bad weather. He realised why drivers are prepared to pay tolls which are by no means cheap; for example, a journey from Washington to New York and back, including travel along the New Jersey Turnpike (a distance of about 500 miles, of which about 220 miles is on the Turnpike), involves a toll expenditure of 6·40 dollars (or about 45s.) for a passenger car. Of this 3·50 dollars is for tolls on the Turnpike itself and the remainder is for bridge and tunnel tolls at the approaches at each end of the Turnpike.

The author was impressed by the general standard of performance and maintenance of the vehicles on toll roads. Most of the passenger cars were new or comparatively new (practically all were of post-war manufacture). Vehicles in poor condition or which, in the opinion of the toll booth operator, appear incapable of a sustained speed of about 50 m.p.h. are not allowed on to most of the toll roads. When driving at night, especially in bad weather, rear lights on cars were easily seen and stop lights invariably worked. The good aiming of head lights and the complete absence of pass lights or other auxiliary head lights was such as virtually to eliminate glare from cars passing along the opposite roadway. Although the rear lights of some commercial vehicles left much to be desired, there was usually such an array of coloured lights on the rear of these vehicles that a commercial vehicle on the road ahead could be recognised as such. The stop lights on commercial vehicles were usually poor, but the flashing indicator lights were usually very good (this could not be said of the indicator lights on some cars).

The relatively uniform power/weight ratio of American cars and commercial vehicles eases traffic problems on roads with high speed limits. In Britain, difficulties would arise on similar roads because of the large differences in the power/weight ratio of cars, the low engine power of commercial vehicles and the poor state of maintenance of many vehicles.

In conclusion, the author felt that a visitor, especially from Britain, could not avoid being greatly impressed by the great network of these modern toll roads. The speed with which they are built and the technical skill and imagination displayed in their design and construction are a measure of the energy with which road problems are tackled in the United States.

### The Clay Plan

At the time this paper was written a plan (The Clay Plan) for the construction of a national system of super highways, intended to satisfy America's road needs for the next ten years, was under consideration by Congress.[11] What effect this plan might have, assuming that it is carried out, on the construction of new toll roads is not known, but it is certain that the existing toll roads will make a substantial contribution to any system of super highways.

### Acknowledgments

The material on which this article is based was collected while the author was serving with the United Kingdom Scientific Mission in Washington, D.C. The author wishes gratefully to acknowledge the facilities made available to him and especially the help and encouragement given by Mr. H. J. Hadow, the director of the mission, and members of his staff. The article is published by permission of the Director of Road Research, United Kingdom.

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# Effect of Interrupted Loading on Mechanical Properties of Metals*

By E. W. EVANS, B.Sc., Ph.D.†

No. II—(*concluded from page 295, February 22*)

*It is found for a range of metals that increased elongation to fracture may be obtained in tensile tests if the specimen is repeatedly loaded and unloaded, the strain increasing by small increments in each cycle. Extra elongation results only if cyclic loading commences at, or prior to, the point of maximum load on the load/elongation curve. It is appreciable only if the strain increment is small and it increases with the strain rate. The correlation of the effect with the hysteresis behaviour of the metals has been attempted with some success. Though Erichsen and Bulge tests on mild steel and α-brass sheet showed no increased ductility, cyclic loading may improve drawing or pressing practice through better lubrication.*

*Non-Ferrous Metals.*—It was possible that the observed phenomenon was a property of steel and not of metals generally, being due to an ageing or carbon diffusion property. The non-ferrous metals were accordingly investigated primarily with the object of ascertaining whether or not a solution should be sought on this basis.

*Aluminium*—Commercial purity aluminium round specimens were tested in the Pendulum Avery machine and showed no increase in total elongation by cyclic loading. However, appreciable extra elongation was recorded when the strain rate was increased by using the University Avery machine; Fig. 12 summarises the results. This shows that the same factors govern the extent of the extra elongation as in steel, e.g. increasing the strain rate resulted in increased elongation to fracture of specimens 9, 15, 13 and 11. Variation of the strain increment per cycle did not affect the total elongation to the same extent as in steel, of specimens 8, 10, 11 and 12.

Fig. 13 shows typical load/elongation curves for aluminium, and this is the only metal that shows a different behaviour below the maximum load point due to cyclic testing. However, since the maximum load was about 0·5 ton, it may be that the test now became susceptible to a small but finite delay between the application of load to the specimen and its registration on the gauge of the testing machine.

This section of the work showed that the phenomenon was not confined to steel, and was therefore not due to an ageing process.

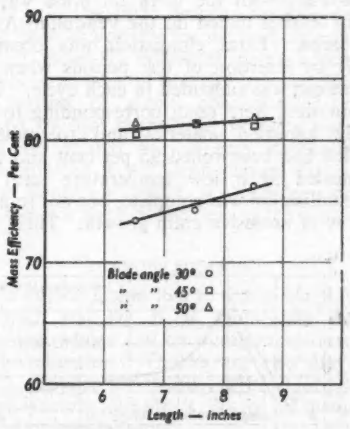


Fig. 13—Specimens two, thirteen and fourteen, showing effect of cyclic loading

*Copper.*—99·99 per cent pure copper wire was annealed at 450 deg. Cent. for one hour after a light pass to straighten the wire. As with aluminium, extra elongation was

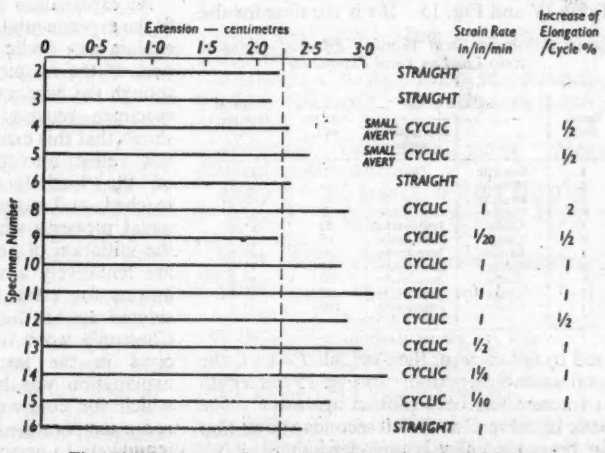


Fig. 12—Summary of experimental results for aluminium

* Report No. MW/B/30/55 of the Solid Mechanics Group of the British Iron and Steel Research Association.

† Formerly an investigator in the Metal Working Laboratories, Sheffield, of B.I.S.R.A.

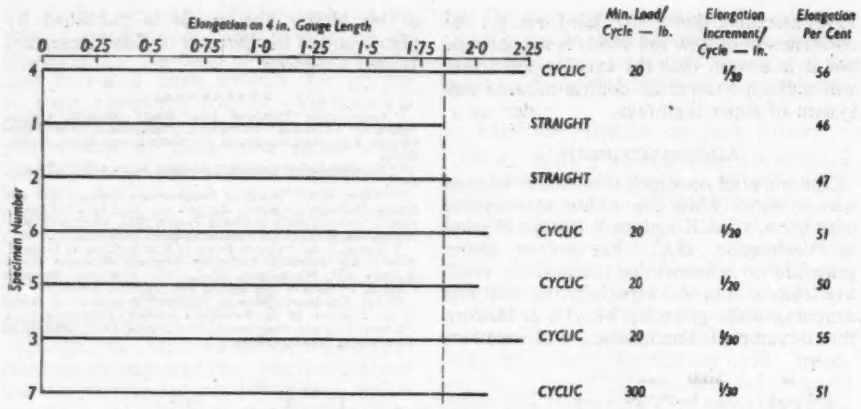
Elongation on 4 in. Gauge Length
0 0·25 0·5 0·75 1·0 1·25 1·5 1·75 2·0 2·25
Specimen Number
Min. Load/ Cycle — lb.
Elongation Increment/ Cycle — in.
Elongation Per Cent
4 CYCLIC 20 1/30 56
1 STRAIGHT 46
2 STRAIGHT 47
6 CYCLIC 20 1/20 51
5 CYCLIC 20 1/20 50
3 CYCLIC 20 1/30 55
7 CYCLIC 300 1/30 51

**Fig. 14—Summary of results for copper wire tensiles**

only obtained in cyclic tests at the higher strain rates. The results of these tests are summarised in Table III and Fig. 14.

TABLE III—*Copper Wire Specimens*

| Specimen | Conditions of test | | Elongation increment, in | Total elongation, in | Elongation, per cent |
|---|---|---|---|---|---|
| | | Min. load per cycle, lb | | | |
| 1 | Straight | — | — | 1·84 | 46 |
| 2 | Straight | — | — | 1·87 | 47 |
| 3 | Cyclic | 20 | 1/30 | 2·22 | 55 |
| 4 | Cyclic | 20 | 1/30 | 2·23 | 56 |
| 5 | Cyclic | 20 | 1/20 | 2·03 | 50 |
| 6 | Cyclic | 20 | 1/20 | 2·05 | 51 |
| 7 | Cyclic | 300 | 1/30 | 2·06 | 51 |

*α-Brass.*—All the work on brass was on strip tensiles pulled on the Pendulum Avery machine. Extra elongation was obtained only by insertion of rest periods when the specimen was unloaded in each cycle. Two grain sizes were used, corresponding to the fully annealed material and to material which had been rolled 95 per cent and then annealed at a low temperature until recrystallisation was complete, but not so as to allow of excessive grain growth. There was

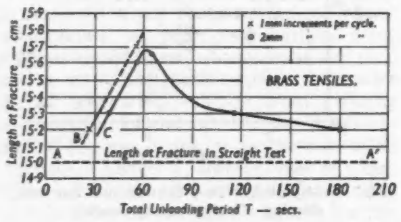


**Fig. 15—Effect of varying the unloading period**

no difference between the behaviour of the fully annealed and the cold-worked and annealed materials. The effect of varying the rest period under no load $t_0$ is shown in Table IV and Fig. 15. If $t$ is the time for the

TABLE IV—*Brass Strip Tensile. Effect of Ageing at Zero Load on Total Elongation*

| Specimen | Conditions of test | | Time at 0 load to, secs. | Length at fracture, cm |
|---|---|---|---|---|
| | | Elongation/ cycle | | |
| 1 | Straight | — | — | 15·0 |
| 2 | Straight | — | — | 14·9 |
| 3 | Straight | — | — | 15·05 |
| 4 | Cyclic | 1mm/cycle | 0 | 15·2 |
| 5 | Cyclic | 1mm/cycle | 30 | 15·7 |
| 6 | Cyclic | 2mm/cycle | 15 | 15·3 |
| 7 | Cyclic | 2mm/cycle | 30 | 15·6 |
| 8 | Cyclic | 2mm/cycle | 40 | 15·65 |
| 9 | Cyclic | 2mm/cycle | 60 | 15·4 |
| 10 | Cyclic | 2mm/cycle | 90 | 15·3 |
| 11 | Cyclic | 2mm/cycle | 180 | 15·2 |

load to fall to zero, then we call $T=t+t_0$ the total unloading period. In Fig. 15 the length at fracture has been plotted against $T$. The peak in curve $C$ at $T=60$ seconds shows that for brass the effect is time-dependent.

*Summary of Experimental Results.*—At this stage the main experimental observations may be summarised as follows :—

(1) Under cyclic loading conditions the total elongation to fracture may be increased by about 10 per cent of the original gauge length.

(2) The effect occurs in both ferrous and non-ferrous metals, but not in a high-carbon steel under the cyclic testing conditions employed.

(3) The difference between a cyclic and normal test, as shown by the load/elongation curve, is that in the former case the maximum load section of the curve may be prolonged beyond the normal fracture region.

(4) The extra elongation depends on the point of initiation of cyclic loading. Extra elongation only results if cyclic loading commences at, or prior to, the point of maximum load in the load/elongation curve.

(5) The extent of the extra elongation depends on the following factors :—

(*a*) Increasing the strain rate results in increased extra elongation.

(*b*) The extra elongation depends on the extent of unloading in each cycle. For mild steel bar tensiles there is a maximum effect when the minimum load per cycle is of the order of 0·2 ton.

(*c*) Appreciable extra elongation results only if the cyclic elongation increment is less than 1 per cent of the gauge length.

(*d*) The extra elongation depends on the rate of unloading. For brass the extra elongation/ageing time at zero load curve shows a maximum in the region of thirty-five seconds ; for steel, at high frequencies of testing, extra elongation is only obtained by interposing rest periods at no load.

## Discussion

An explanation of the observed effect must fit the experimental results outlined above and explain why cyclic loading enables the hardness of the incipient neck zone to increase though the hardness of the remainder of the specimen remains unchanged. (4) above shows that this extra hardening mechanism is not called into play until the maximum of the load/elongation curve has been reached, and suggests that it depends on a metal property which becomes operative at the initiation of necking. Some suggestions are tentatively advanced of possible mechanisms for extra hardening, which is considered to be the basic phenomenon. In Chaston's work on lead,[2] which has been cited in the introduction, a satisfactory explanation was based on recrystallisation, which for cold-worked lead may occur at room temperature. However, such an effect is unlikely to occur in the metals which have been investigated here, for which the recrystallisation temperatures are considerably above room temperature.

The true stress/strain curve has been plotted for a series of tests on mild steel round specimens, Fig. 16. Points have been

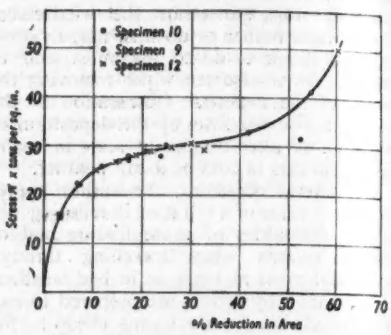


**Fig. 16—Stress/strain curve for mild steel bar tensiles**

plotted for both continuous and cyclic loaded specimens and it will be seen from the figure that one curve may be drawn through all the points, except in the region where necking has begun and consequently accuracy is low. The formation of multiple necks is sufficient to explain the identity of the stress/strain curve for both testing methods. As a consequence of cyclic loading the incipient neck zone occurs at different points along the gauge-length as the specimen is elongated, so that the diameter of the incipient neck zone remains constant and, hence, the specimen may sustain the maximum load over a larger elongation. On the stress/strain curve this will give superimposed points until necking is confined to one part of the gauge length, when the stress increases rapidly to fracture. It appears, therefore, that no useful information may be derived from consideration of the stress/strain curve.

Because of (2), an explanation cannot be sought in terms of the ageing phenomenon, although this may have some effect in the case of brass, for which there is a definite dependence of extra elongation on the rest interval at no load.

Normal strain hardening may be explained by the dislocation theory, where it is visualised as a process of progressive complication of the dislocation pattern as the dislocation density increases. Taylor[6] sought an explanation of hardening in terms of the intracrystalline domain walls which were considered to act as obstacles to slip. Another mechanism for the strain hardening would be the removal or inactivation of innate lattice defects which become dislocation sources, generally known as dislocation mills. Elimination or locking of such sources would harden crystals, the dislocations that were initially present being rapidly used up by slip. Orowan[7] discusses reasons for and against these hardening mechanisms and concludes that intracrystalline strain hardening cannot be due to innate obstacles to slip, or to the exhaustion or inactivation of an innate stock of dislocation or dislocation mills. He considers that the most probable hardening mechanism is due to the creation of lattice injuries acting as obstacles to slip in the course of deformation, i.e it is identical with Taylor's explanation except that the obstacles are not innate, but are generated during deformation.

These, then, are the mechanisms which have been suggested to account for normal strain hardening. It is possible that one or more of the above hardening processes may either become operative or operate to a

greater extent under cyclic loading. It is possible to suggest one process by means of which a Frank-Read source may become inoperative. The shear stress ($\tau$) required to operate dislocation mills of the Frank-Read type depends on the stress needed to drive a dislocation through the lattice, being given by a relationship of the form :

$$\tau = \tau_d + Q,$$

where

$\tau_d$ = the dislocation driving stress

and

$Q$ = the shear stress required to start the dislocation mill operating in the absence of a driving stress.

$\tau_d$ would be expected to increase with increasing strain, since this implies a larger concentration of dislocations and consequently a higher back pressure on the source. However, on load, the mill will continue to generate dislocations, since they move away, and so allow fresh dislocations to move out. On unloading, all sources cease to generate dislocations and remain inactive until the specimen is again loaded. Reloading subjects sources in the more highly deformed regions to a larger back stress, so that a higher stress will be required to activate these than in sources elsewhere in the specimen—the result is a shifting of the region of concentrated deformation (the incipient neck zone), along the gauge length.

This suffices to explain the summarised results given under (1), (2) and (3) on page 326. An explanation of (5(*b*)) follows readily if it is assumed that unloading brings compressive microstresses into play, which operate in the region of the source, tending to lower the dislocation density in its neighbourhood. Such a decrease in dislocation density would result in a smaller value of $Q$ depending on the extent of unloading. The hysteresis loops which are reproduced in Fig. 17 show that it is only at very small

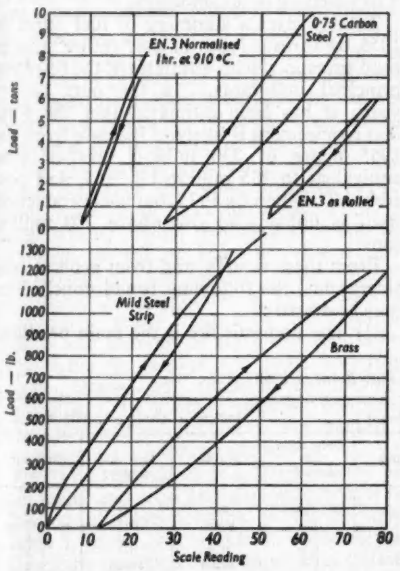


**Fig. 17—Stress/strain hysteresis curves for various materials**

loads that appreciable departure from linearity of the unloading curve occurs, and hence that it is at such low loads that the compressive microstresses begin to operate. There are, therefore, two effects in opposition, viz. (*a*) a locking of sources due to unloading and reloading, and (*b*) an easing of source operation due to compressive microstresses on unloading. Since these two effects are in opposition, it would be expected that there would be an optimum minimum load per cycle which yielded maximum extra elongation. A neck may be regarded as a stress concentrator which, once it has developed beyond some critical magnitude, serves to confine the deformation to the region of the neck. At the maximum load a large strain increment will result in a considerable decrease in diameter of the neck, which will then act as a stress concentrator in opposition to the threshold stress effect due to cyclic loading. By such reasoning, the experimental results (4) and (5(*c*)) above may be explained.

It was suggested that further information about metallurgical changes that might occur during cyclic loading could be obtained by considering the hysteresis behaviour during the course of the tensile test. The curves given in Fig. 17 were obtained using the Lamb extensometer and indicate that the loop width varies considerably for the metals investigated. High carbon steel and $\alpha$-brass give wide loops, whereas the metals which show extra elongation have narrow loops. The loop width is, in effect, a measure of the reverse strain on unloading, and this suggests that the extra elongation depends on the amount of reverse strain in a cycle.

Since there was such a qualitative connection between the loop width and the presence or absence of the extra elongation effect, it was decided to investigate the hysteresis behaviour at various stages of deformation. This investigation showed that no variation of loop width occurred between initiation of straining and fracture. Since the cyclic loading effect increases with strain rate, it might not have occurred in the present Lamb extensometer tests which were at slow strain rates. Further work along these lines, but using a fast response, automatic load/elongation measuring instrument might yield more significant information.

## Experimental Results.—Part II

Extra elongation was obtained by cyclic loading in uni-axial tensile tests as described in Part I of the Experimental Results. It was thought that a similar effect might be observed under the bi-axial straining conditions which are operative in deep drawing and pressing operations. Consequently, Erichsen and Bulge tests were carried out on mild steel and brass sheet.

(*a*) *Erichsen Tests.*—The blanks were cleaned, some being used dry and some well coated with various lubricants. In the cyclic pressing tests the punch was advanced in stages of about $^1/_5$mm in each cycle, being withdrawn between each forward stroke until it exerted no pressure on the cup sides, a procedure which was repeated until the cup fractured. Care was taken that (1) the blanks were uniform in size, (2) the blanks were clamped uniformly in all the tests and (3) the end point was defined by the first appearance of fracture.

Tables V and VI, for mild steel and brass respectively, show that the presence of calcium oleate on the blank increases the cup depth possible either in a straight or cyclic test. The effect of cyclic stressing is too small to be significant.

(*b*) *Hydrostatic Bulge Test.*—This test has been described by Mellor and Loxley[8] where a full description is given of the apparatus and experimental procedure. Cyclic and straight tests were made using the same apparatus, the procedure in the cyclic tests being to release the hydrostatic presssure and then reapply it in the same way as the load was cyclically applied in the tensile test. Mild steel strip was used, the cycle being defined by increasing the oil pressure to obtain constant small increments in the polar height of the cup. No increase in cup depth to fracture resulted under the experimental conditions, although extra elongation was obtained in cyclic tensile tests on the same material.

Table V—*Erichsen Tests on Mild Steel Sheet*

| Specimen | Mode of testing | Lubrication | Cup depth, mm |
|---|---|---|---|
| 1 | Straight | None | 11·3 |
| 2 | Straight | None | 11·0 |
| 3 | Cyclic | None | 11·5 |
| 4 | Cyclic | None | 11·3 |
| 5 | Straight | Calcium Oleate | 12·5 |
| 6 | Straight | Calcium Oleate | 12·5 |
| 7 | Cyclic | Calcium Oleate | 12·5 |
| 8 | Cyclic | Calcium Oleate | 12·1 |

Table VI—*Erichsen Tests on α-Brass Sheet*

| Specimen | Mode of testing | Lubrication | Cup depth, mm |
|---|---|---|---|
| 1 | Straight | None | 14·5 |
| 2 | Straight | None | 14·5 |
| 3 | Straight | None | 14·8 |
| 4 | Cyclic | None | 14·9 |
| 5 | Cyclic | None | 14·9 |
| 6 | Cyclic | None | 14·9 |
| 7 | Straight | Calcium Oleate | 15·0 |
| 8 | Cyclic | Calcium Oleate | 15·3 |
| 9 | Cyclic | Calcium Oleate | 15·7 |
| 10 | Cyclic | Calcium Oleate | 15·7 |

The present work indicates that, although extra elongation may be obtained in a tensile test, it does not follow that cyclic loading will result in increased ductility in practical applications such as the manufacture of pressings. The main reasons for this are : (*a*) It must be possible for the necking region to shift about the deformed metal, which is usually impossible in pressing practice where the regions of stress concentration are defined by tool shape. (*b*) Pressing operations are carried out at very high strain rates whereas it has been shown that the extra elongation effect is time-dependent and does not occur at high testing frequencies.

## Acknowledgements

The author would like to thank Mr. J. G. Wistreich and Dr. B. B. Hundy for their continued advice and encouragement during the investigation. Thanks are also due to Mr. J. Hopper for modifying the Universal Avery Machine and Mr. R. Bly for his meticulous experimental work.

## Appendix

*Mild Steel Bar Tensiles.*—Steel specification, B.S. 970—En 3. 1½in diameter bar. Mean grain diameter=0·03mm.

Analysis : C 0·17 ; Si 0·21 ; Mn 0·61 ; S 0·04 ; Ni 0·16 ; Cr 0·12 ; Sn 0·13 ; P 0·033. Large grain size. Mean diameter=0·06mm.

*Mild Steel Strip.*—Mean grain diameter=0·02(5)mm.

Analysis : C 0·055 ; Mn 0·37 ; P 0·010 ; S 0·038 ; Ni 0·052 ; Cr 0·078 ; Sn 0·010 ; N 0·0035.

*Aluminium.*—Commercial purity. Mean grain diameter=0·07mm.

Analysis : Fe approx. 0·001 ; Mg 0·01 ; Si approx. 0·01 ; Cu approx. 0·001 ; Al 99·97.

70/30 *Brass.*—Mean grain diameter=0·05mm.

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# Mechanical Engineers and Clean Air

By SIR EWART SMITH, M.A., Vice-President I.Mech.E.*

*Last week the Institution of Mechanical Engineers held a Conference at the Central Hall, Westminster, on "The Mechanical Engineer's Contribution to Clean Air." It opened on Tuesday evening, February 19, and continued over the following Wednesday and Thursday. Here we reprint long extracts from the opening lecture, entitled "Some Technical and Economic Aspects involved in the Reduction of Atmospheric Pollution." In broad terms it reviews the whole problem.*

## The Clean Air Act

THIS conference follows naturally on the passing of the Clean Air Act of 1956, and this Act, in turn, is largely based on the excellent and realistic report of the Government Committee on Air Pollution under the chairmanship of Sir Hugh Beaver. In this Act, the Government have wisely avoided writing in rigid and detailed technical provisions; they have, instead, enunciated general principles on which regulations are to be framed. It is to be hoped that these technical regulations will be introduced in stages, and be so phrased that industry and the engineers responsible may know what is required and be able to take effective action. They will also need to be revised periodically in the light of administrative experience, and as new technical knowledge becomes available.

## The Engineer's Role in Combating Pollution

Our broad objective must be to make any discharge to atmosphere sufficiently innocuous, having regard to local conditions, topography and climate, for the inhabitants of the area to suffer no significant and avoidable discomfort from dirt, corrosion, loss of sunlight or injury to health. While this may be a counsel of perfection, it is certain that existing knowledge is sufficient to enable real progress to be made. It is unfortunate, however, that, both in Parliament and in the press, too little regard is usually paid to the difficulties, cost and time which must be involved in effecting a major improvement, however strong may be the urge to achieve it.

Whatever type of pollution we have to deal with, it is clear that first-class design and good technical operation of processes or equipment are of fundamental importance. The mechanical engineer's contribution is, therefore, crucial, and on him ultimately falls the main burden of improvement. It is he who is primarily responsible for translating into reliable working plant, at minimum operating and capital cost, the ideas and scientific knowledge produced by patient research and development in many fields. An important part has to be played also by those concerned with complementary activities, including chemists, chemical and electrical engineers, physicists (including instrument engineers), and by fuel technologists and metallurgists.

If the same care and thought were given to the design of effluent treatment plant as is given to the main parts of process equipment, many of the complaints now made would be avoided; we must do better in future by treating this matter with the seriousness it deserves. But here, as in so many of the problems which we face as an industrial community, a crying need is for a greater supply of engineering technologists trained, able and eager to apply scientific knowledge to practical ends on both the design and user sides.

* Imperial Chemical Industries, Ltd.

## Effects of Pollution and Measures for Improvement

It may be appropriate to summarise, broadly, the ways in which pollution can affect the community, and the main lines along which improvement may be sought:

Air pollution can cause harm or annoyance to the community due to:

(1) The deposit of discrete particles of grit and dust.

(2) The deposit of tarry matter and liquids.

(3) The corrosion of metal, stone and fabrics, due to gases or solutions such as sulphur dioxide, sulphuric acid, hydrochloric acid, nitric oxide, nitric acid, sulphuretted hydrogen, &c.

(4) Obscuration of the sky.

(5) The direct effect on health by inhalation or absorption of noxious gases, condensed fumes or dust. In future atomic radiation must also be included, but it is certain that steps will be taken to keep this within safe limits as nuclear processes are developed.

It is obvious that there are four major lines of attack on the pollution problem; all should be followed or at least be fully explored, if the most rapid advance is to be made:

(i) *Improve the Method of Operating Particular Processes in Order to Reduce the Creation of Noxious Effluent.*—There is no need to elaborate on the direct, as well as the indirect, benefits of improving operational efficiency. However good a plant may be, there is usually scope for advance which nearly always leads to economic gain, in addition to the amelioration of pollution. The admirable work now being carried out by the National Industrial Fuel Efficiency Service shows what improved results can be obtained in this way.

(ii) *Install (or improve) Subsidiary Equipment for Removing as far as Possible the Pollutants at the End of the Process.*—Typical examples of this approach are the use of cyclones, electrostatic precipitators, &c.

Later in this conference there are to be several papers dealing with equipment of this kind. It may be noted, however, that very considerable advance has been made in recent years in the design of cyclones, particularly of the multi-unit type, and of filters for dust removal. At the same time, it would appear that for many purposes, the electrostatic precipitator is necessary to give effective results.

(iii) *Change the Process Itself.*—It is clearly impossible here to discuss processes, whether these are of a relatively simple nature, such as methods of firing boilers and kilns, or those concerned with the infinitely more complex production methods of the chemical, the oil and the metallurgical industries. However, with the rapid advance of scientific knowledge, it is obvious that the scope for improvement in efficiency and cleanliness is almost unlimited. A comparison of modern chemical plants, or of oil refineries with their forerunners of even twenty-five years ago, will show the progress which is being made. But large-scale work of this kind demands very large numbers of highly qualified technologists to carry out the research, development and scientific design which are essential.

(iv) *Increase the Height of Effluent Discharge.*—In theory, this is probably the most obvious and simplest method of minimising the immediate results of pollution. It is, too, the only known practicable method of reducing the harmful effects of gaseous effluents, such as $SO_2$, without incurring serious technical complication and heavy monetary cost.

## Scope of the Problem

Apart from certain specialised processes, particularly in the chemical, metallurgical, cement-making, mining and quarrying industries, the main causes of pollution arise from the combustion of carbonaceous matter for direct heating or steam-raising.

Table I gives a summary of fuel burnt in 1955 by various types of user (other than in road transport) with estimates of the resulting principal pollutants. In the next twenty years, it has been estimated that the total fuel requirement is likely to increase from the 1955 figure of 230 million tons of coal equivalent to 285 million by 1965, and possibly 340 million by 1975, but coal production itself is unlikely to rise above 230 million tons.

From these figures, and from general considerations, the following broad conclusions may be drawn:

(1) The domestic fire is the main producer

TABLE I—*Summary of Fuel Burnt in* 1955

| Class of consumer | Fuel burnt | | | Pollutants discharged, million tons | | |
|---|---|---|---|---|---|---|
| | Solid | Liquid | Coke oven gas (unpurified) | Smoke | Grit and dust (c) | Sulphur dioxide |
| Coal: | | | | | | |
| Domestic | 38 | — | — | 0·9 | 0·1 | 0·9 |
| Electricity works | 43 | — | — | small | 0·3 | 1·2 |
| Railways | 13 | — | — | 0·3 | 0·1 | 0·4 |
| Industrial and miscellaneous (a) | 67 | — | 1·0 | 0·8 | 0·3 | 1·8 |
| Coke ovens (b) | — | — | 1·6 | small | small | 0·1 |
| Gas works | 6 (d) | — | — | small | small | 0·2 |
| Coke: | | | | | | |
| (Excluding consumption in gas works and blast furnaces) | 15 | — | — | nil | small | 0·4 |
| Oil: | | | | | | |
| Diesel and gas oil | — | 3·8 | — | small | nil | 0·1 |
| Fuel oil | — | 5·4 | — | small | nil | 0·3 |
| Creosote-pitch mixture | — | 0·8 | — | — | nil | small |
| Total | 182 | 10·0 | 2·6 | 2·0 | 0·8 | 5·4 |

(a) Includes general industry, collieries, patent fuel works, non-industrial establishments, waterworks, and the Service Departments.
(b) Although over the whole country the smoke and grit discharged from gas works and coke ovens is small, the pollution from certain types of plant and particularly from older coke oven plants can have a serious local concentration.
(c) This column does not include grit and dust emissions, estimated as about 0·5 million tons, from industrial processes other than steam raising.
(d) Coke.
Sources: Beaver Report and Ministry of Fuel and Power Statistical Digest, 1955.

of smoke and it is emitted at a low level ; the next largest producer is general industry. The steam locomotive is a smaller though serious contributor of smoke, discharged at low level and often in congested areas. Railway smoke will, however, be virtually eliminated within fifteen years by the introduction of diesel and electric traction.

(2) Coal-fired power stations and general industry are the major producers of grit and dust. The problem of removal has been substantially solved technically, and dust from these sources will steadily diminish as, under the Act, all new units of any appreciable size in the future must have efficient combustion arrangements, effective dust arresters, and high chimneys for the dispersal of the very fine residual dust and fume. In the present state of technical development, there does remain a slight opacity of the effluent from even the best installations which we may still expect to be the subject of some adverse comment as standards improve. There are, however, many things to be done before a serious attack on this residium would be justified. The task of dealing with the vast numbers of existing small and medium-size plants is a serious one and will take long to complete.

(3) Coal and oil consumption in general industry will only rise slowly, since the pattern of industrial development is such that electricity rather than steam will provide most of the energy for the increased production which is expected. The increased future production of electricity will itself come mainly from nuclear energy.

(4) The iron and steel industry, including the associated coke ovens, will have difficulty in reducing the total mass of pollutants, which they produce ; improvements will be made but, as output is rising rapidly, it will be an uphill task to reduce the total mass of noxious effluent. This is unfortunate, since some of the worst black spots are caused by the heavy concentration of this industry within small areas. The same comment is true of the cement industry, where the dust problem is particularly intractable. Both industries may, however, develop improved methods of production (as, for example, with the wider use of electric furnaces by the time there is a sufficiency of power from atomic energy in the latter part of this century).

(5) The general conclusion must be that, even assuming the most energetic action and benefit from fresh inventions, smoke in large towns, though steadily decreasing, will be with us for at least the fifteen years envisaged by the Beaver report, mainly because of the magnitude of the problem of converting many thousands of industrial plants and millions of small domestic units. The latter is perhaps the most important single factor, but presents no technical difficulties. Its solution depends on public education and on political action, backed, if necessary, by economic inducement.

(6) The removal of $SO_2$ from effluent gas has major technical and economic difficulties and no effective solution is yet in sight. Table I shows that all fuels, including oil, contribute to this serious form of pollution. Processes for the removal of sulphur oxides from power station flue gases by washing have been in commercial operation in Britain for over twenty years. They are so costly that they have been installed only in three power stations in the world (only two now operate), and all are in Central London. Such plants are also difficult to operate and maintain, and are at present not practicable for industrial boiler installations. In addition, these processes cool the gas to such an extent that even with a high stack and 97 per cent removal of $SO_2$ the maximum concentration at ground level may only be reduced by some 25 per cent, though the total effect is much reduced (Hawkins and Nonhebel, 1955). The best, and reasonably successful, palliative, for $SO_2$, other gases, and residual fine dust, is high discharge of the effluent from the minimum number of chimneys.

(7) Another serious source of damaging pollution is the motor vehicle, with its discharge of oily vapours ; in addition, the petrol engine also discharges carbon monoxide. The latter seldom accumulates to concentrations prejudicial to health, but the oily vapours certainly cover street furniture and buildings with an oily film which has become much more noticeable with the increase in diesel powered vehicles. Opinions on the damage to health are divided, but observation shows that they affect vegetation. The saving of fuel by more complete combustion would unfortunately be small, but this must not deter the mechanical engineer from developing engines with nuisance-free exhausts.

## Analysis and Measurement of Atmospheric Pollution

The correct approach to atmospheric pollution, as to any other technical problem, is to study the process concerned critically step by step and in detail from raw materials to final product and effluents. It is possible —with the march of science it is indeed probable—that the process can be modified to produce as good, or even better, results with less atmospheric pollution at no greater cost ; but with both existing and alternative methods of manufacture, it is necessary to consider all the steps concerned, particularly those involving the transfer of heat. Reduction of pollution and increase in efficency will frequently go hand in hand.

Effective analysis invariably demands measurement, for example, of thermal efficiency and of rates of heat transfer, including monitoring and/or control with the aid of suitable instruments. This point can be illustrated by the case of three Lancashire boilers with coking grates and economisers which had been run on conventional lines for some twenty years with an average annual efficiency of 72 per cent. In 1947, these boilers were placed under the control of scientifically trained engineers who were experienced in the operation of large water-tube boilers. At a cost of some £2000 they installed additional instruments and made minor improvements based on knowledge which is readily available, but seldom applied appropriately and comprehensively to this type of installation. As a result, the average annual efficiency has since been raised to 80 per cent, and the cost of the improvements was recovered in less than two years. Not only was there greater efficiency, but there was the additional benefit of a reduction of invisible pollutants such as $SO_2$ because less total fuel was used. A good example of complete change in the method of manufacture is in the pottery industry, where it has been found that continuous tunnel kilns heated by gas or electricity give a better product at a lower cost than the old conventional type of coal-fired bottle kilns which are such heavy smoke producers.

The complete flow sheet of any process should invariably include a statement of the volume and analysis of any effluents. These effluents must be considered not merely in terms of concentrations of undesirable components, but also in terms of the weight emitted per day, and of the effect on the community ; this effect will be related to the location of the factory—whether, for example, it is by the sea or in a narrow valley—for not all that goes up a chimney necessarily comes down on land, owing to the prevailing winds crossing the narrow dimensions of this island. Thus, for the country as a whole, Meetham (1950) has estimated that only one-third of the carbonaceous smoke, and four-fifths of the $SO_2$ reach the ground.

In dealing with effluent problems, whether in connection with existing or new plants, the engineer must have information on the probable size of the solid particles, and of the expected composition of the gases. This information may be difficult to obtain, particularly in regard to solid pollutants, as there is usually insufficient knowledge of the concentration and size of dust particles entering dust arresters. Moreover, information from small-scale experiments is more or less valueless. This lack is due to the considerable cost in both money and skilled manpower in obtaining reliable data. The principles of accurate sampling are now known, but too little attention is given during design to the layout of flues so that samples across the whole area of the flue can be taken cheaply and expeditiously. At present, thorough testing is seldom carried out on any but the largest plants, and even then may not be followed up by repeat measurements, at suitable intervals, to confirm that the performance of the equipment has not fallen off for any of the many reasons which may affect it. There is, therefore, a pressing need to develop a rapid, and preferably automatic method of monitoring the discharge from dust extractors. There is need, too, for research into the general form of flue arrangements to assist sampling, to be followed by the codification of the results in a form for ready use by the designer.

The dust discharge from pulverised fuel water-tube boilers presents one of the worst problems. The rapid increase of pulverised fuel firing took place because it was until recently the only method available for firing very large boilers, owing to the limitations of size of the mechanical grate. Some of the early installations were bad offenders and rectification is costly. In an industrial boiler plant presenting no special difficulty, £500,000 is being spent to supplement cyclones with electrostatic precipitators and provide a higher chimney of 300ft. The coal consumption is about 500,000 tons a year.

The following operating results from a modern pulverised fuel boiler may be of interest. They represent the average of six tests between September and November, 1956. The plant burns per hour 14 tons of coal with 21 per cent of ash at a load of 275,000 lb per hour of high-pressure steam.

Table II—*Average Dust Burden in Flue Gas*

From boiler ... ... 3·15 grains per cubic foot at N.T.P.
From cyclone ... ... 0·427 grains per cubic foot at N.T.P.
From precipitator ... 0·055 grains per cubic foot at N.T.P.

| Location | Total dust deposited, tons per day | Per cent |
|---|---|---|
| In furnace ... ... ... ... | 44·0 | 62·2 |
| In cyclone hoppers ... ... | 23·0 | 32·7 |
| In precipitator hoppers ... | 3·1 | 4·4 |
| Up stack ... ... ... ... | 0·5 | 0·7 |

The average dust burden in the flue gas is shown in Table II.

It may be noted that planning consent to the erection of this plant contained the provisos that (*a*) the flue gases, without dilution, carried not more than 0·4 grain of solids per cubic foot, of which at least 0·25 grain must be less than 20 microns, and (*b*) the chimneys were to be not less than 250ft in height ; they are, in fact, 300ft.

The current development of the cyclone method of firing large boilers is promising ;

most of the inerts are collected as molten slag, and there is a reduction in the dust going forward from the furnace to about one-eighth of that in a normal pulverised fuel boiler. It remains to be seen whether this form of firing is widely suitable for British coals, and whether the residual fine dust can be collected with such efficiency that the total solids discharged to atmosphere are appreciably less than from conventional pulverised-fuel-fired plant, and what are the relative costs.

heights of 250ft to 350ft or more are necessary.

(3) A stack itself creates downdraught eddies, as shown in Fig. 1. These can be minimised by increasing the velocity of discharge and by suitable design of the stack mouth, as is shown by recent developments in the design of ships' funnels. It would seem that a similar intensive study might be advantageous for land installations.

(4) Theory indicates, and practice confirms, that it is advantageous to combine in a single stack the discharge from as many effluent producing units as possible. (The rapid increase in the cost of chimneys in relation to their height also leads to the same conclusion.) Table IV clearly illustrates this point, and also shows how the ground level concentration falls with increasing height.

material in suspension in the air above will, as a first approximation, absorb light in proportion to its projected area; Fig. 2 shows the increase in projected area when a sphere of 1cm diameter is successively subdivided into smaller and smaller spherical particles.

From Fig. 2 it is clear that if a discharge of 0·1 grain per cubic foot of dust particles of 20 microns diameter appeared as only a slight haze, the discharge of the same weight of dust as 1 micron particles in the same volume of gas would appear as a relatively heavy cloud. As an illustration of this point, Table V shows the relation between the reduction in the blackness of a plume in comparison with the estimated rate of ground deposit as cyclone arresters of increasing efficiency are installed on the small boiler plant to which reference has already been made in Table III (Stairmand, 1955).

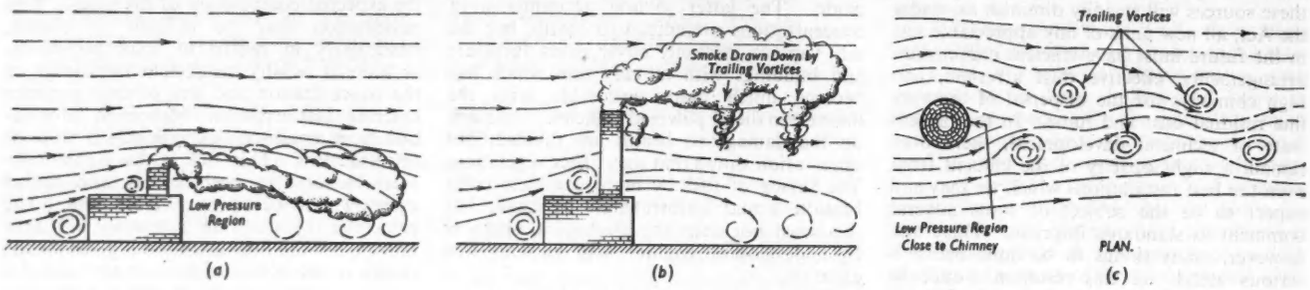



Fig. 1—Effects of building and chimney wakes

An example of estimated dust deposition from which useful deductions can be drawn is given in Table III. This refers to a small grate-fired boiler on three-shift working, burning 1¼ tons per hour of coal of average ash content and shows the effect of fitting four types of dust arrester (Stairmand, 1955).

TABLE III—*Estimated Dust Deposition*

| Type of arresters | Calculated maximum dust deposit rate, oz per sq. yd per year | Tons of dust deposited per year in circle of 500 yards radius |
|---|---|---|
| None ... ... ... ... | 217 at 70 yards | 120 |
| (*a*) Scroll type ... ... ... | 1·0 at 120 yards | 1·8 |
| (*b*) High-throughput | 0·4 at 200 yards | 0·9 |
| (*c*) High-efficiency cyclone | 0·3 at 240 yards | 0·6 |
| (*d*) Multi-cyclone ... ... | 0·15 at 230 yards | 0·3 |

In a plant of this kind it is evident that little is gained in dust collection by installing arresters of more elaborate type than (*a*) or (*b*), but they may have other advantages (Table V).

TABLE IV—*Estimates of Maximum Ground Level Concentrations of $SO_2$ from a Battery of Five Boilers, Each Burning 1¼ tons per hour of Coal, Calculated by Method of Appendix VI, Beaver Report*

| Chimney height, feet | 80 | | 120 | | 200 | |
|---|---|---|---|---|---|---|
| Chimney mouth velocity, feet per second | 25 | 50 | 25 | 50 | 25 | 50 |
| | Parts per million | | | | | |
| One boiler only ... | 0·42 | 0·32 | 0·28 | 0·22 | 0·17 | 0·13 |
| 5 boilers, 1 chimney | 0·62 | 0·54 | 0·41 | 0·36 | 0·25 | 0·21 |
| 5 boilers, 5 chimneys | 2·1 | 1·6 | 1·4 | 1·1 | 0·85 | 0·65 |

TABLE V—*Improvement in Appearance of Smoke Plume from a Small Boiler Plant*

| Type of arrester | Emission as percentage inlet | Reduction in average ground deposit rate within 500 yard radius, per cent | Reduction in plume blackness, per cent |
|---|---|---|---|
| None ... ... ... ... | 100 | Nil | Nil |
| Scroll collector ... ... | 29 | 98·5 | 19 |
| High-throughput cyclone | 19 | 99·2 | 38 |
| High-efficiency cyclone | 9 | 99·5 | 60 |
| Multi-cyclone ... ... | 7 | 99·7 | 65 |

## Considerations Governing Chimney Height

As the conference does not include a paper on the specific subject of chimney height, I should like to mention in rather more detail some aspects of this important subject.

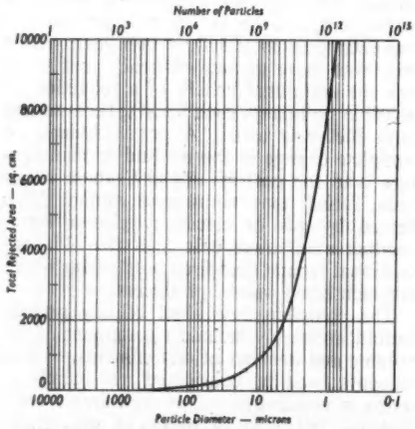
As a result of direct measurement and observation *in situ*, and of wind tunnel experiments, much is now known of the influence of chimney height on the dispersal of both solid and gaseous effluents. The following are some of the more important general points :—

(1) The "plume" tends to expand at a solid angle of about 20 deg. under normal wind conditions.

(2) Any buildings or sudden obstructions adjacent to the stack will cause a downdraught on the lee side likely to affect the air currents, to a height of one and a half to two and a half times the height of the obstruction. For isolated plants, therefore, the stack should be some two and a half times higher than any associated buildings to ensure that the plume of smoke, gas and solids is not brought down quickly to ground level. Fig. 1 illustrates this point. On general grounds it is, of course, obvious that the higher the stack, the greater will be the dispersion and the smaller the concentration of "fall out" at any point. Hence, for power stations and many industrial plants stack

## Obscuration of the Sky

The total mass of solid particles discharged and their settling rates are by no means the only concern of the engineer charged with minimising air pollution; it is necessary also to consider the effect of particles of dust and smoke on the obscuration of light. It is generally agreed that any appreciable reduction of ultra-violet light can create a serious detriment to health. Any fine




A sphere of 1cm diameter (density 2·3) weighs 1·2 grammes

Fig. 2—Increase in projected area when a sphere 1cm in diameter is subdivided into uniform spheres

## The Costs of Pollution and the Price of Improvement

Engineers are concerned not only with technical problems, but have, in addition, to consider costs. Before concluding, therefore, I should like to give some estimate of the costs and savings which may be involved in achieving the level of amenity visualised by the Clean Air Act. Any such figures can be only the broadest approximations and may well be in error between the limits of ±25 per cent. However, they may give some idea of the effects on the national economy of the action which is contemplated.

The Beaver Committee estimated that the direct costs of pollution are some £250 million per annum, and this makes no allowance for readily avoidable loss due to incomplete combustion, which may be put at not less than £25,000,000 per annum. Oxides of sulphur play a major part in the corrosion of structures and the rotting of fabrics, but it is at present not possible to visualise how the bulk of such pollutants can be eliminated. Taking this into account, and making some allowance in practical terms for residual pollution of other kinds, it would appear reasonable to assess the possible direct and indirect monetary savings at, say, £100–£150 million per annum.

When we turn to the capital costs of remedial measures, little published data exists; what there is refers mostly to the cost of equipment proper and does not

include the cost of installation, which may well bring the total up to two or three times the price of the equipment. In the case of large units which are straightforward, and which work continuously, such as the one quoted earlier in this paper, the addition or improvement of dedusting apparatus may amount to around £1 per ton of coal per annum. The relative cost will, however, rise rapidly with decreasing size and with the physical difficulties of installation where space is cramped; it will also increase if the plant only operates on one or two shifts. Taking all these aspects into consideration, and after making allowance for installations which already reach a tolerable standard, it would not be unreasonable to assume an overall average figure of between £2 and £4 per ton of coal per annum. If, then, we take the mean figure of £3 per ton of coal per annum, and apply it to the figures in Table I, we arrive at a total of some £550 million. In addition, we have to allow for the costs of treating effluent arising from industrial operations other than straight combustion. At a guess, this might be put at between £50,000,000 to £100 million, giving a total of, say, £625 million.

The following estimates of cost on a sectional basis provide an alternative method of arriving at the overall costs :—

| | Capital cost £ million |
|---|---|
| (1) Mechanical grates on small furnaces : | |
| (*a*) It is estimated that there are about 40,000 hand-fired boilers. Taking into account size and alternative conversion to coke or oil firing, the average cost may be taken as £1000 per unit ... ... ... | 40 |
| (*b*) It is also assumed that some 2000 process furnaces will need conversion at a cost of, say, £2500 each, giving a total of ... ... ... ... | 5 |
| All this capital expenditure should give a good return through the resulting saving of fuel | |
| (2) Dust arresters : | |
| We can exclude from this table provision of dust arresters on very large plants such as power stations, since they are mostly already installed. | |
| All plants must in future, however, have some dust arresters. | |
| (*a*) It is estimated that medium-efficiency cyclones will become necessary in respect of a consumption of 20,000,000 tons per year of coal by industry working one shift per day. The corresponding capital cost will be approximately ... ... ... ... ... | 40 |
| (*b*) In addition, much more expensive electrostatic precipitators may ultimately have to be installed in larger installations (burning about 30,000,000 tons per year of coal), including boilers, metallurgical and cement plants, &c., on continuous shift ; the corresponding cost will be approximately ... ... | 60 |
| (3) Higher chimneys : | |
| The estimated extra cost of the higher chimneys which will be required on existing and new plants for effluents from combustion and other processes... ... | 50 |
| (4) Domestic premises : | |
| A recent estimate of the cost of installing smokeless heating and cooking appliances in smoke control areas is (Goulden, 1956) ... ... ... ... ... ... ... ... ... | 175 |
| (5) Extra coke-making capacity : | |
| It is estimated in Appendix XI of the Beaver report that the carbonising capacity required above the normal increased production of the gas industry during the next fifteen years (to correspond with (4) above) would be 10,000,000 tons per year of coal. Sir Henry Jones estimates that the cost of large new carbonising plant is £15 5s. per ton per year of coal carbonised. (Symposium on Coke, 1955.) This estimate includes the whole gas plant required to pump the gas into a gas grid, and is for production of coke suitable for improved open fire grates. The cost would, therefore, be ... ... ... ... ... ... ... ... ... ... ... ... | 155 |
| Total... ... ... ... ... ... ... ... ... ... ... | 525 |

It will be seen that the figure thus arrived at is in reasonable accord with the broader estimate of £625 million already made. This expenditure would be spent over a period of at least fifteen years. The rate of expenditure might, therefore, be taken as being in the region of £40,000,000 per year, if evenly spread over the period which has been assumed. This is about 3 per cent of the net annual expenditure on domestic fixed capital formation in 1955. Hence the cost of implementing the Clean Air Act, though burdensome, cannot be regarded as intolerable.

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# Mechanical Strength of Power Transformers in Service*

By E. T. NORRIS, M.I.E.E.†

*The mechanical stresses in power transformers have steadily increased with transformer size and supply system capacity. Using only simple mathematics, it is shown that the mechanical strength of a transformer is not a simple single value as is implied in the short-circuit clauses of standard transformer specifications. Some of the strains are progressive, and some of the stresses cumulative, leading to short-term and long-term characteristics. The resulting categories of mechanical strength are defined as initial, critical and ultimate, the last-named being usually the crucial one. It is shown how the performance in service can be predetermined and the expectation of life in terms of number of short-circuits, predicted for any given operating conditions. Service records of failures on short-circuits are analysed and found to support the predicted values. Methods of improving the expectation of life are considered.*

MANY papers have been published during the last forty years dealing with mechanical stresses in transformer windings. On the other hand, very little publicity or attention has been given to the mechanical performance of transformers in service. This is perhaps because this performance has been apparently good and reassuring. Failures due specifically to mechanical stresses are rare, though, of course, serious when they do occur. The position is actually not quite so satisfactory. Mechanical stresses are usually unsuspected, and their effects are often obscured by different and more serious stresses occurring after the initial failure. Moreover, the major forces are cumulative in effect,[1, 2] so that final failures will not necessarily be due to a severe fault, but may be the culminating effect—in other words, the last straw. Notwithstanding these conditions, short-circuit stresses have frequently caused serious trouble in the past and seem likely to cause even more in the future.

It is proposed in the paper not to derive formulæ for calculating forces and stresses, as this has been done extensively and in detail in published literature,[3–14] but to study the effect of these forces on the life and performance of transformers in service under normal and abnormal operating conditions.

### Present Position

Apart from the experience described above, there is a general assumption that mechanical stresses are not alarming, because most national transformer specifications demand that the transformer shall satisfactorily withstand a short-circuit with full line voltage maintained, i.e. with infinite system capacity behind the transformer.[15, 16, 17]

It is believed that manufacturers have acquiesced in these requirements, because (*a*) such severe conditions cannot arise in service, (*b*) a test compliance is not practicable, and (*c*) they do not know that their transformers would not meet the test. It is likely, therefore, that manufacturers have treated this guarantee as a risk that can be commercially accepted, whilst purchasers and users have assumed that it was a technical guarantee fully covered by an adequate factor of safety. This distinction has been discussed elsewhere.[18] The false sense of security thus engendered has recently been exposed by Stenkvist.[19] In an extensive search of published literature he could find only two records of short-circuit tests on large power transformers.[20, 21] An additional case is described in reference 1, but none of the tests complies fully with the national specifications corresponding to full voltage being maintained on the transformer. To complete the picture, reference 22 describes the only known case of a short-circuit test of full value, but here the transformer was only 1200kVA, which is hardly representative of modern large transformer practice.

The subject, nevertheless, is of great importance as abnormal conditions may occur at any time. There is a continuous growth in system capacities. The rupturing power of circuit breakers has increased during the last twenty-five years from 1500MVA to 25,000MVA, or more. The short-circuit current permitted by system planning engineers is generally based on this value and has increased accordingly.

The universal practice of auto-reclosing makes deliberate and repeated switching on to possible faults a normal practice. The more recent development of fault throwing, in which phase-to-earth fault throwers are used for inter-tripping purposes, seems likely to grow. This involves deliberately creating a dead short-circuit under normally controlled conditions. Further, owing to the growth of system capacity, many transformers are now operating under short-circuit mechanical-stress conditions much more severe than those envisaged when they were designed. This trend is likely to continue into the future.

*Forces at Work.*—The principal forces at work are radial and axial. In concentric winding transformers, radial forces involve adequate support of the inner winding whilst the outer winding relies upon the tensile strength of the conductor. For all but very large transformers these limits suffice, and radial stresses have not generally been regarded as serious. It has recently been suggested[14, 19] that the mechanical characteristics of the copper or aluminium conductor may be of vital importance, [and this aspect is considered later in the paper].

Axial forces include an unavoidable compression of both windings and a displacement due to electromagnetic dissymmetry. This may be caused by any of the following :—(*a*) tappings in the windings ; (*b*) inaccuracy of assembly ; (*c*) shrinkage of insulation due to impregnation and drying out ; (*d*) compression of the insulation in service ; (*e*) the necessity for a whole number of turns in a coil ; (*f*) the necessity for a whole number of coils ; (*g*) oil cooling ducts ; (*h*) conductor transpositions ; (*j*) insulation reinforcement and grading ; (*k*) the different voltage and current ratings of the two windings to be balanced.

If the windings are interleaved or sandwiched, as is usual in shell type construction, instead of being concentric, the radial and axial forces become interchanged in the foregoing description. [The author then discussed radial strength and axial strength of windings. His remarks on the influence of the displacement force on axial strength are reproduced here.]

*Displacement Force.*—The displacement force is usually ignored in published literature. It is one of the main purposes of the paper to suggest that, on the contrary, it is the most serious and dangerous force to be considered and that it is responsible, somewhat insidiously, for most, if not all, failures in service due to mechanical stresses.

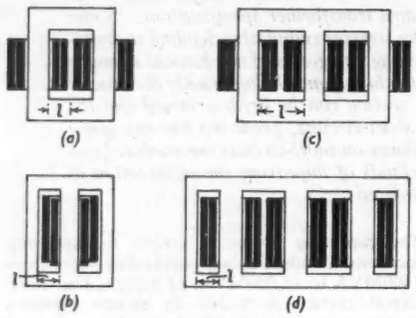
The force in question is a repulsive one between the two windings. In theory it is zero if the two windings are electromagnetically perfectly balanced. In practice it may apparently and initially be small and controllable, especially in the larger transformers where it is not seriously accentuated by tapping asymmetries. These factors may account for the general disregard of it in published literature. Moreover, even if the windings are perfectly balanced, and this can

* Abstract, Supply Section paper, Institution of Electrical Engineers. London, February 27, 1957.

† Consulting engineer with Ferranti, Ltd.

only be done theoretically on paper, the position is, alarmingly, one of unstable equilibrium, like an egg standing on end. In practice some initial dissymmetry is unavoidable. In one case where the electromagnetic balance was perfect in design the windings moved in opposite directions in two phases in a short-circuit test[21] of an 80,000kVA transformer, owing to unavoidable small asymmetries in erection.

Fig. 1 shows the four principal winding arrangements of core-type transformers. A small




(*a*) Single-phase two-leg.
(*b*) Single-phase one-leg.
(*c*) Three-phase three-leg.
(*d*) Three-phase five-leg.

**Fig. 1—Principal winding arrangements for core-type transformers**

axial displacement is drawn diagrammatically in Fig. 1 (*b*). The effective displacement is not necessarily a physical movement of the whole winding but the resultant of the component asymmetries of the electromagnetic centres, and may be due to any of the causes (*a*)–(*k*) listed above.

The stress for a simple dissymmetry, as shown in Fig. 1 (*b*), is given by the formula

$$p=\frac{0\cdot043L}{wal}\frac{S}{f}x \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $p$ is the stress per 1 per cent axial displacement of the electromagnetic centres.

The difficult term in this formula is $l$, the effective length of the radial flux-leakage path. It is an important term in transformer design as it affects calculations of the reactance and eddy-current losses in the windings as well as the mechanical forces, and it has been much studied.[13, 14, 22, 23] Fortunately, for the present purpose, we are concerned with the maximum stresses in the winding, and these will be where $l$ is a minimum. This almost always occurs in the window of the core, where its usual value is simply as shown in Fig. 1. Thus, the force is greatest on the part of the periphery of the windings in the window or under the yokes.[8, 11, 13] Short-circuit failures in service generally show this concentration. Fig. 2 shows a typical example.

Incidentally, it will be seen from Fig. 1 (*c*) that $l$ for a single-phase fault (i.e. a fault to earth) on a three-phase, three-leg transformer, is much larger than for the other constructions, and this type of core is most favourable in this respect.

List of Symbols

$a$—Net area of winding insulation support, square inches.
$b$—Percentage compression of electromagnetic centres per ton per square inch stress.
$c$—Percentage compression of axial insulation per ton per square inch stress.
$C$—Crushing strength of insulation and supports, ton per square inch.
$d_0$—Percentage initial axial displacement of electromagnetic centres.
$d$—Percentage final axial displacement of electromagnetic centres.
$f$—Frequency, cycles per second.
$K_i$—Ideal short-circuit strength as a multiple of full-load rating.
$K_0$—Initial short-circuit strength as a multiple of full-load rating.
$K_c$—Critical short-circuit strength as a multiple of full-load rating.
$K_1$—Ultimate short-circuit strength due to axial stresses.
$K_r$—Ultimate short-circuit strength due to radial stresses.
$K_s$—Short-circuit stress in service.
$l$—Length of radial flux leakage path, inches.
$L$—Axial length of winding, inches.
$n$—Number of short-circuits.
$p$—Axial stress, tons per square inch per 1 per cent dissymmetry. Crest asymmetrical value at full load.
$P$—$I^2R$ loss in winding, kilowatts.
$S$—Rating, kilovolt-amperes per phase.
$t_1$—Total conductor axial insulation thickness, per unit of $L$.
$t_2$—Total winding spacer and washer insulation thickness, per unit of $L$.
$t_3$—Total end insulation thickness, per unit of $L$.
$w$—Effective radial width of leakage flux path, inches.
$W$—Width of core window, inches.
$x$—Per unit reactance.

For a transformer of the same rating and with the same windings but with a five-leg core, as shown in Fig. 1 (*d*), the mechanical stresses in the outer phases will be nearly doubled and the short-circuit strength correspondingly reduced.

The displacement force gives the maximum pressure at the ends of the winding against the yokes or clamping rings. The compressive force [discussed in a preceding section of the paper] gives the maximum pressure in the middle of the windings. In practical application the two formulæ are combined to give a resultant axial force which may be a maximum towards either middle or ends—frequently the former initially and the latter eventually.

## Summary of Mechanical-Strength Categories

The foregoing development shows that the mechanical short-circuit strength of a transformer is not a simple single value, even when all the parameters are known and the formulæ are correct. The various ways in which a transformer can fail mechanically under short-circuit conditions are summarised as follows :

*Ideal Strength*, $K_i$.—This is the mechanical strength assuming perfect design, perfect construction and perfect electromagnetic balance of the windings. There is practically no cumulative effect as the force increases little with movement of the windings. Failure usually occurs in the middle of the winding. This strength is mainly of academic interest but does serve as an interesting bench mark to show how far the practical values in service fall below the ideal.

$$K_i^2=\frac{0\cdot022CL^2}{wlp} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

*Initial Strength*, $K_0$.—This is the mechanical strength against a single short-circuit giving stresses equal to the crushing strength of the coils or insulating materials. No allowance is made for the displacement increasing and thus in turn increasing the stress. It is perhaps the best indication of the performance of the transformer under the short-circuit tests prescribed in national standard specifications.

$$K_0=\sqrt{\frac{C}{pd_0}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\text{or} \quad \frac{1}{K'_0}=\sqrt{\left(\frac{0\cdot5}{K_0^2}+\frac{1}{K_i^2}\right)} \quad . \quad . \quad . \quad (4)$$

*Critical Strength*, $K_c$.—If the force per unit displacement of the electromagnetic centres of the windings equals or exceeds the pressure per unit compression of the windings, the condition is unstable and the force will go on increasing until failure occurs irrespective (theoretically) of the mechanical strength of the windings or their supporting structure. The analogy mentioned in the section on " Displacement Force " is then reached of the egg standing on end.

A considerable number of faults or a prolonged short-circuit will be necessary before this limit is reached, and $K_c$ is therefore the multi-short-circuit strength, assuming perfect initial winding balance (i.e. $d_0=0$).

$$K_c^2=\frac{1}{p_1b_1+p_2b_2} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

*Ultimate Strength*, $K_1$.—Since no transformer can be perfectly balanced in practice, owing to the various causes enumerated, (*a*)–(*k*) above, there will always be some initial dissymmetry $d_0$. The actual strengths for a large number of short-circuits will therefore be less than the critical value $K_c$ due to this initial dissymmetry and will also depend upon the winding mechanical strength.

$$K_1^2=\frac{K_c^2K_0^2}{K_c^2+K_0^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

*Radial Strength*, $K_r$.—The limiting strength here is the tensile strength or the elongation characteristic of the conductor. It has not hitherto been treated in technical literature as being of serious consequence, but the analysis given [in the section on " Radial Force "] shows that for the larger transformers now being built it may well be a limiting factor. It can be progressive in effect and thus affect the life of the transformer in service. Since its value is determined by the mechanical characteristics of the conductor there is little scope for control in design.

$$K_r=6\cdot5\sqrt{\frac{L}{P}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

*Service Stress*, $K_s$.—The practical requirement with which all the foregoing strengths have to be compared is the short-circuit current which can occur in service. It depends, of course, on the supply system and transformer impedances and is frequently a complex calculation forming part of the system planning and sometimes having several values depending on circuit conditions. So far as the transformer manufacturer is concerned, it is too frequently an unknown and unascertainable quantity. It may also increase in service for a particular transformer as the system capacity grows, as discussed above.

**Fig. 2—Short-circuit failure of 60MVA, 132kV transformer**

## Mechanical Strength of Coil Stacks

Analysis of mechanical characteristics of the insulation [as in a previous section of the paper] permits determination of the behaviour of the winding under short-circuit stresses but gives no indication of the end-point. i.e. the breakdown value. This can only be studied by tests, preferably full-scale, on stacks of coils built up exactly as in practical assembly of the transformer.

An extensive study of this kind has been carried out on many stacks of coils including the following variables : (*a*) thickness of the conductor insulation ; (*b*) cross-section of the conductor ; (*c*) transposition of strands ; (*d*) type of spacing material ; (*e*) type of winding : disc, helical, &c.

Each stack was mounted in a hydraulic press. The pressure was applied slowly and steadily, and continuous records of pressure, compression, time and behaviour of the winding were photographed by a slow-motion cinefilm. The interrelation of these characteristics could then be analysed in detail by study of the film. Short-circuits between strands were indicated on an ammeter by changes in current flow.

The criterion of failure depended not only on these records but also on a number of observers stationed around the press who indicated the point of failure on the film by a lamp signalling code. Failure was defined as any actual breakdown between turns or strands or as the first sign of any form of distortion of the coils apart from straightforward compression.

The weakest point was frequently a tendency for the conductors to turn over. That this is representative of incipient failure in service is

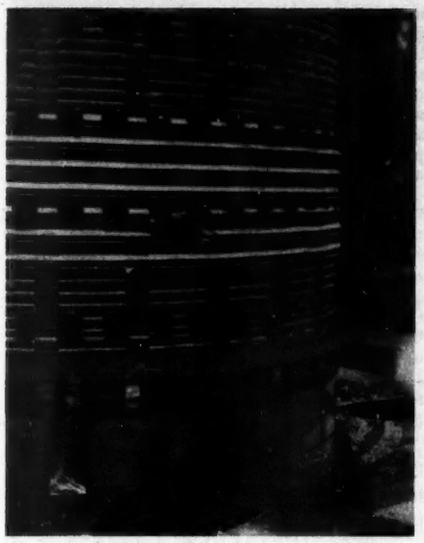


Fig. 3—Mechanical failure of 60MVA transformer l.v. winding

shown by Fig. 3, which is taken from a short-circuit failure of a 60MVA, 132kV transformer.

From these tests, values of $C$ range from 2·0 to 4·0 tons per square inch, depending on the factors (*a*)–(*e*) above. Less meticulousness in observation would have led to more favourable results.

As a final example, six typical designs of three-phase, three-limb transformers are compared in Table I. Two coil-stack strengths ($C$=2·0 and 3·0) are assumed and three types of coil insulation : (*a*) a British Standard type II pressboard with $c$=5·8 ; (*b*) a hard pressboard with $c$=1·3, and (*c*) a synthetic resin varnished paperboard with $c$=0·5. The effect of initial electromagnetic asymmetries of zero and 0·5 per cent is also included.

TABLE I—*Typical Transformer Mechanical Strengths*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Coil stack strength $C$ ... ... | 3 | 3 | 3 | 3 | 2 | 2 | 14 |
| Coil insulation ... ... ... | *a* | *b* | *b* | *c* | *a* | *b* | *d* |
| Initial displacement, $d_0$ ... | 0·5 | — | 0·5 | 0·5 | 0·5 | 0·5 | 0·5 |
| $K_t$ ... ... ... ... ... ... | 15·2 | 15·2 | 15·2 | 15·2 | 12·4 | 12·4 | 33·0 |
| $K_0$ ... ... ... ... ... ... | 12·9 | 15·2 | 12·9 | 12·9 | 10·5 | 10·5 | 27·9 |
| $K_s$ ... ... ... ... ... ... | 5·4 | 8·15 | 8·15 | 9·2 | 5·4 | 8·15 | 12·3 |
| $K_1$ ... ... ... ... ... ... | 5·2 | 8·15 | 7·4 | 8·1 | 5·1 | 7·1 | 11·7 |

Study of these examples leads to the following generalised conclusions from the hypothetical parameters :

(i) The ideal strength $K_t$ is ample for all designs.

(ii) Provided that the transformer reactance is over 10 per cent, all designs will pass the standard short-circuit tests of the national standard specifications. This is true even where the usual soft pressboard is used.

(iii) No designs will be completely short-circuit proof in service unless the transformer reactance is well over 12 per cent. This is true even if the windings are perfectly balanced initially ($d_0$=0).

(iv) Notwithstanding (iii) many transformers will still have satisfactory life in service.

(v) The lower coil-stack strength reduces the resistance to single short-circuits, $K_0$, but has little effect on the multi-short-circuit service strength, $K_1$ (Fig. 5).

(vi) The standard short-circuit tests, therefore, are sensitive to the coil-stack strength or initial dissymmetry, but give little indication of the performance in service, $K_1$.

(vii) There is no marked dependence of strength on apparent power rating. Dimensionally the strengths $K$ are inversely proportional to (kilovolt amperes)$^{0·125}$, from equations (1) and (3). This slight dependence is apparently obscured by other factors [one of which is referred to in the paper].

(viii) The life in service depends largely upon the compression modulus of the insulation.

## Performance in Service

It is very difficult to obtain practical evidence of the performance of power transformers in service as far as short-circuit stresses are concerned. In a modern well-run system, dead short-circuits are rare—rates have been suggested to the author varying from 0·1 to 1·0 per transformer per annum. Other factors making failures specifically attributable to mechanical stresses difficult to identify are referred to in Section 1 of the paper.

*Analysis of Failures in Service.*—The practical evidence the author has been able to collect (summarised in Table II) is mostly provided by two periods of exceptional—in fact, freakish—operating conditions, outside normal practical possibilities :

TABLE II—*Records of Mechanical Failures*

| Case | MVA | $K_s/K_1$ | $K_1/K_s$ | $n$(calculated) | $n$ (actual) |
|---|---|---|---|---|---|
| A | 60 | 1·66 | 0·71 | 6·5 | 14 |
| B | 60 | 1·66 | 0·71 | 6·5 | 5 |
| C | 60 | 1·66 | 0·71 | 6·5 | 3 |
| D | 60 | 1·33 | 0·88 | 16 | 14 |
| E | 60 | 1·00 | 0·81 | ∞ | — |
| F | 30 | 1·21 | 0·91 | 26 | 23 |
| G | 30 | 1·21 | 0·91 | 26 | 28 |
| H | 30 | 0·88 | 0·84 | ∞ | — |
| J | 60 | 1·46 | 0·84 | 13 | 16 |
| K | 60 | 1·20 | 0·96 | 44 | 33 (*a*) |
| L | 20 | 1·10 | 0·88 | 34 | 28 (*b*) |
| M | 20 | 1·10 | 0·88 | 34 | 28 (*b*) |
| N | 80 | 1·00 | 0·80 | ∞ | — |
| O | 80 | 1·96 | 0·80 | 7 | 3–9 |
| P | 40 | 1·25 | 0·86 | 20 | 9–15 |
| Q | 20 | 1·92 | 0·88 | 10 | — (*c*) |
| R | 2·5 | 1·48 | 0·89 | 15 | — (*d*) |

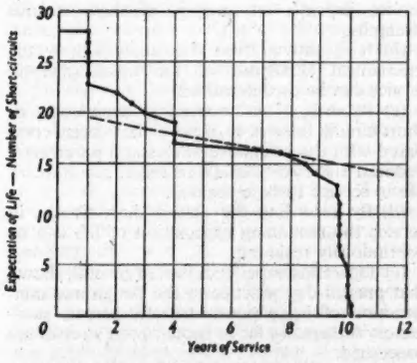
(*a*) No failure occurred.
(*b*) Partial failure.
(*c*) Failed after eight years' service.
(*d*) Failed after nine years' service.

Values in this table are calculated from accurate design formulæ taking full account of the complex winding characteristics of a large power transformer—not from the simplified formulæ given in the paper. The value of initial axial displacement of the electromagnetic centres assumed is the design value if that is greater than 0·5 per cent, and 0·5 per cent if it is less, to allow for actual possible displacements in assembly.

Cases A, B, C concern three transformers, designed in 1929, with an electromagnetic displacement due to difference in ampere-turn distribution of 0·8in, or 1·2 per cent. After these failures this dissymmetry was corrected and case D resulted. The damaged transformers were rewound with balanced windings (on paper) and a harder type of pressboard for the coil washers and spacers. Case E shows the resulting improvements. No failures have occurred on these transformers.

Cases F and G refer to two transformers feeding the two circuits of a double-circuit line. These transformers, like the previous ones, had two periods of abnormal operation, as shown in the short-circuit history of one of them plotted in Fig. 4. The group of short-circuits in the early years was due to excessive fog flashovers, as recorded in Reference 24. There followed a period of normal service and then another abnormal period of short-circuits due to trailing barrage balloon cables accentuated by an unusually exposed position of the substation.

The normal operation condition, as shown by the dotted line in the figure, indicates a normal short-circuit life of fifty-four years. When these transformers were rewound the improvement shown in Case H was made, owing to development in design in the intervening twelve years.




Dotted line indicates normal operating conditions showing an expected life of fifty-four years.

Fig. 4—Service record of short-circuits on 30MVA transformer

Cases L and M, concerning two transformers in parallel, are of particular interest, since partial failure due to short-circuit stresses was detected before actual failure, so that the mechanical strains were not obscured by breakdown damage.

These two transformers were designed for parallel winding on-load tap-changing gear. A differential current transformer was connected in the parallel halves to detect differences in current in the course of tap-changing. Since the parallel halves cannot be perfectly balanced there is a negligibly small "spill" current during normal operation. This current was recorded periodically, and after a time a gradual increase was noticed. This was caused by a small movement of the windings due to short-circuit stresses—a movement that superficial examination in service would not have detected. The movements were found on all six phases in differing degrees, thus emphasising the progressive nature of the strains due to short-circuits. These transformers had also had a very severe short-circuit history. Rectification was thus possible before damage had been done.

Cases N and O concern a transformer which had undergone a short-circuit test.[22] The working condition is shown at N and the short-circuit test condition at O. The failure during the short-circuit test—which was accentuated well beyond the service condition, though still within the full infinite power value—is predicted by the calculations.

Case P also deals with a short-circuit test.[1] This transformer passed the test—again in accordance with prediction.

In most cases one of the windings is mechanically weaker than the other, and values in the table are given for this winding. In Case Q, the calculated strengths of both windings (this was a single concentric transformer) were the same within a few per cent. When the transformer was examined both windings were found to have failed.

Case R was unusual in that failure occurred in a tertiary winding—again as calculated. In Cases Q and R no record of the number of short-circuits was available, but the ages of the transformers are given as some guide to the service life.

The results of all this service experience in supporting the method of predetermining the short-circuit strength are assembled in Fig. 5.

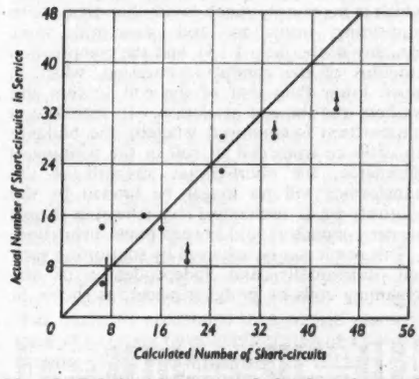



Fig. 5—Relation between calculated and actual number of short-circuits from service records

These results as a whole are perhaps somewhat pessimistic in relation to present day manufacture, because all of the transformers concerned were designed over twenty-five years ago.

Analysis of Table II leads to the following conclusions :—

(*a*) None of the transformers failed in service unless predicted by the calculations.

(*b*) All failures occurred in the winding calculated to be weakest mechanically.

(*c*) In Case F, where two windings were calculated to be equally weak, both failed.

(*d*) Of the two transformers short-circuit tested, one failed and one withstood the test—both as predicted.

(*e*) The increase in life through improving the

electromagnetic balances in the windings was as calculated (Case D).

(*f*) In cases F and G failure occurred in the h.v. winding instead of the more usual l.v. winding—again as predicted.

(*g*) The progressive nature of short-circuit failure in service is shown clearly in Cases L and M.

(*h*) The predicted life agrees with the actual life to the degree shown in Fig. 5.

*Expectation of Life in Service.*—A preliminary estimate of the expectation of life of a transformer may be made by considering, in each particular case, the local severity of short-circuits, i.e. the value of $K_0$, and the local frequency of short-circuits per annum. The expected life in years can then be deduced from the equation‡

$$N=\frac{\log\left(1+\frac{K_0^2}{K_c^2}-\frac{K_0^2}{K_0^2}\right)}{\log\left(\frac{K_0}{K_c}\right)^8}$$

where $N=n/9$. It is likely that in the majority of cases this study will give a satisfactory assurance of long service, and short-circuit stresses need not be considered a serious matter.

Where there seems to be a practical limitation, or where the actual faults in service are unusually frequent or serious, a record can be kept, as shown in Fig. 4. Taking this as an example, the transformer had a normal life of fifty-four years (Table II, Case G). It used up 19·3 years of this expected life in the first 3·5 years of actual service and thirty-one years in the last 2·5 years of service. This was, of course, an abnormal case and far from representative of practical operating conditions, but it illustrates the method suggested.

*Possibilities of Improvement.*—The radial strength $K_r$ is not usually a practical limitation, and technical literature does not suggest that safe tensile stresses in the copper have hitherto been exceeded in practical operation. Although the damage, i.e. the strain, due to the radial forces may be progressive [as explained in the paper], the stresses are not cumulative, as in the axial strength, so that the ultimate conditions are more definitely circumscribed.

The axial strength $K_1$ can be increased by any of the means described [in the paper], and these methods have accounted for the generally satisfactory performance of large power transformers in service, especially where the frequency of short-circuit faults is within the limits normally imposed by good operating practice.

Two limits inherent in the normal construction are the crushing strength of the coil stack *C*, which is necessarily much lower than that of the supporting insulation and structural work (roughly in the ratio 1 : 5), and the compression modulus of the conductor covering, which is much lower than that of the coil spacers and washers and the end insulation. If, therefore, a construction is employed whereby the building up of force from coil to coil in the winding is eliminated, the short-circuit strength of the transformer will no longer be limited by the relatively weak mechanical characteristics of soft copper conductors and fibrous paper insulation.

This result can be achieved by supporting each coil individually and independently of the remaining coils by bridging pieces, as shown in Fig. 6. The forces of each coil are then transferred to a number of solid columns of insulation which can be designed to meet the required mechanical stresses free from limitations imposed by electrical and technical winding considerations. This " bridge " construction[1] naturally increases the size and cost of the transformer and is not normally necessary, but it can be employed when required to meet particularly severe operating conditions. A typical example of the improvement obtainable is given in column 7 of Table I.

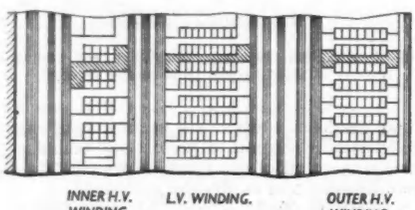



**Fig. 6—Cross-section of windings showing " bridge " construction**

‡ This equation is developed fully in the paper.

## Standard Short-Circuit Ratings

Reference has been made to the short-circuit ratings prescribed in national standard specifications such as References 15, 16 and 17. The relevant clauses stipulate that the transformer must be capable of withstanding a short-circuit on its terminals with full line voltage maintained on the supply side.

This rating is unrepresentative of practical operating conditions in two major respects. In one of them it is much too severe, and in the other too lenient. Unfortunately, the severity and the leniency do not cancel.

(*a*) The requirement that full line voltage must be maintained means a supply system of zero impedance, i.e. of infinite capacity. This is, of course, impossible. The test is also impracticable, as short-circuit testing stations do not exist[19] of sufficient size to carry out such tests on large power transformers. This is recognised in the I.E.C. Recommendations,[15] and in other cases no actual test is specified even as a special or type test. Most specifications allow the inclusion of the impedance of " direct-connected apparatus " either as part of the specification or by agreement with the purchaser. This permits, for example, the inclusion of the generator impedance for generator-transformer units.

It is suggested that the minimum external impedance, including direct-connected apparatus and the supply-system impedance, shall be specified by the purchaser and the resulting short-circuit rating marked on the name-plate.

(*b*) The specifications call for a single short-circuit. A duration is also specified, but that concerns the thermal effects of the short-circuit and not the mechanical stresses. The strength for a single short-circuit corresponds to $K_0$ and this is shown in Table I to be, in general, much higher than the strength $K_1$ for a number of short-circuits. The implication, therefore, in the national standards that a transformer complying with the specification is necessarily, or even probably, short-circuit proof in service is false.

Owing to the progressive and cumulative nature of the stresses, a number of fully asymmetrical short-circuits are required in any short-circuit test if the results are to be conclusive. At least ten are suggested, suitably spaced to avoid excess temperatures. It is also necessary that after the test the windings shall be dismantled and carefully examined for signs of damage or coil distortion.

If these stringencies make short-circuit tests more difficult they will, at least, not result in fewer being made than hitherto.

## Conclusions

(*a*) The mechanical strength of a transformer under short-circuit is not a simple single value as is generally assumed, even when the formulæ are correct and all the parameters are known both for design and for service conditions. Some of the strains are progressive and some of the stresses cumulative, leading to short-term and long-term characteristics. The resulting performance in service depends on analysis of these various strengths.

(*b*) It is shown from this analysis how the mechanical behaviour of the transformer in service can be predetermined.

(*c*) Records from operating experience of short-circuit failures in service have been compared with the calculated values and parameters deduced therefrom, enabling the expectation of life in service to be estimated.

(*d*) By recording the actual short-circuits in service the remaining expectation of life can be continuously reviewed.

(*e*) Operating experience has, in general, shown that present-day practice in the design and construction of large power transformers is satisfactory hitherto as far as short-circuit stresses are concerned.

(*f*) Additional strength can be obtained when necessary to meet unusually severe conditions.

(*g*) The standard short-circuit rating prescribed in national standard specifications[15, 16, 17] is inadequate and may be quite misleading, as it gives little or no indication of the performance of the transformer under short-circuit conditions in service.

(*h*) For the reasons detailed, short-circuit stresses are becoming of increasing frequency and severity, making the mechanical strength of large power transformers and their expectation of life a matter of serious concern.

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# British Standards Institution

*All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.*

## COMPRESSED ASBESTOS FIBRE JOINTING

No. 2815 : 1957. Price 3s. This standard deals with two grades of compressed asbestos fibre jointing : grade A, for use with water, inert gases, inert liquids or steam up to 950 lb per square inch and 950 deg. Fah. (67 kg per square centimetre and 510 deg. Cent.) ; and grade B, for use with water, inert gases, inert liquids or steam up to 250 lb per square inch and 450 deg. Fah. (18 kg per square centimetre and 230 deg. Cent.).

The high temperatures and pressures in grade A mean that the products field of application has been extended considerably beyond that dealt with in B.S. 1737 and B.S. 1832.

## AUXILIARIES FOR OPERATION OF FLUORESCENT LAMPS

No. 2818 : 1957. Price 6s. 6d. With the publication of B.S. 1853 : 1956 (the revised standard for tubular fluorescent lamps for general lighting purposes) it was decided to issue a new British Standard for accessories for fluorescent lamps on a.c. 50 c/s supplies. Parts 1 and 2 of this standard, for ballasts and capacitors, have now been published. The object of the standard is to give the characteristics of the auxiliaries which are essential for the proper operation of lamps complying with B.S. 1853 (Class MCF/U). It also deals with the satisfactory and safe operation of the auxiliaries themselves. The present edition is limited to ballasts and capacitors required for the operation of 80W 60in mains-operated tubular fluorescent lamps used with starter operation on 50 c/s alternating current supplies. Requirements applicable to lamps of other sizes are to be added in a later edition. Definitions are given in the "General" section of the standard. Part 1 includes a section on the classification of ballasts ; and sections on general requirements, tests and marking for ballasts and capacitors are given in Parts I and II respectively. Part III, " Starters," is in course of preparation.

# Electrical and Allied Plant

ON February 22 the Monopolies and Restrictive Practices Commission's report on the supply and exports of electrical and allied machinery and plant was published by H.M. Stationery Office (price 11s. 6d. ; by post 12s. 2d.) The report covers three main classes of equipment : (*a*) Steam and water-driven turbo-alternator plant of not less than 300kW maximum continuous rating. (*b*) Alternators, other than those included under (*a*), and of not less than 10kVA rated output ; d.c. generators of output not less than 0·75kW per 1000 r.p.m. and of not less than 0·75kW actual rating ; a.c. motors of not less than 1 h.p. at any speed ; and d.c. motors of output not less than 1 h.p. per 1000 r.p.m. and not less than 1 h.p. actual rating. (*c*) Transformers of not less than 5kVA rated output.

The report is signed by the following members of the Commission : David Cairns, Q.C. (chairman), T. J. Barnes, Alan Birch, W. L. Heywood, I. C. Hill, Arnold Plant, C. E. Wrangham (subject to note of dissent about exports), R. E. Yeabsley, J. A. R. Pimlott (secretary).

Below we reproduce abstracts from the final chapter of the report : "Conclusions on the Public Interest and Recommendations."

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The value of the total production in the United Kingdom of machinery covered by our reference was £88,000,000 in 1952, and is probably about £100,000,000 per annum at present. Of this total nearly one-half falls within class (*b*), the rest being divided more or less equally between classes (*a*) and (*c*). About one-third of the total production is exported ; the exports are divided fairly evenly in value between the three classes of machinery.*

The principal trade association for manufacturers of electrical products is the British and Allied Manufacturers' Association (Incorporated) (BEAMA) and most of the important manufacturers of the products with which we are concerned belong to it. Nearly all the manufacturers who are parties to the principal practices on which we have to form a judgment are members of BEAMA, but the practices are not operated by BEAMA and not every member of the Association who makes these products is a party to the practices. The practices are operated under the agreements of the Groups, or in some cases under agreements sponsored by The International Electrical Association, Ltd. (I.E.A.) and only those manufacturers who are signatories of the agreements are normally† parties to the practices. As far as class (*a*) is concerned, independent production—that is production by a manufacturer who is not a signatory of any of the agreements for that class—is negligible ; but one of the largest manufacturers, C. A. Parsons and Co., Ltd., now negotiates prices with the Central Electricity Authority on a partly independent basis [as described elsewhere in the report]. There is also very little independent competition with the Group manufacturers of large transformers in class (*c*) and of the larger machines in class (*b*). There is substantial independent production of motors in class (*b*) and of small transformers in class (*c*).

Agreements providing for common prices have existed continuously from the 1930s to the present time in respect of the supply in the home market of nearly all types of product covered by our reference. Agreements governing export markets are generally of later development, and it is only since 1939 that agreements providing for common prices in export markets have been made for most of these products.

Some forty United Kingdom manufacturers are signatories of one or more of the Group and I.E.A. agreements with which we are concerned. Five of them have more widespread interests than the rest and between them are responsible for more than half of the total sales of products covered by our reference. There is no evidence that the five companies can determine the policy of Groups whose membership is relatively large, that is, generally, those concerned with the smaller machines. For large machinery the number of manufacturers is much smaller, and there is no doubt that these companies have a preponderant influence. Two of the companies, Metropolitan-Vickers Electrical Company, Ltd., and the British Thomson-Houston Company, Ltd., are subsidiaries of Associated Electrical Industries, Ltd., and are together responsible for more than one-third of home supplies of machinery in class (*a*).

The principal restrictive practice we have to consider in relation to the public interest under all the heads of our reference is the observance of minimum prices : with few exceptions its effect is that the manufacturers concerned charge common prices.

*Common Prices.*—The case put forward by the manufacturers in justification of their arrangements is set out fully in Chapter 32 [of the report]. They argue that : (i) the industry has an exceptional need for stability ; (ii) stability is exceptionally difficult to achieve without price agreement ; (iii) price competition would have disastrous effects on the industry, on the buyers and on the national economy ; (iv) the system of common prices is justified by results ; (v) the level of common prices adopted is justified by the moderate level of profits for the industry ; (vi) The apparently wide spread of costs does not reflect a corresponding spread of manufacturing efficiency and (vii) the least efficient manufacturer whose capacity is needed should, in any event, have the livelihood which the level of prices under the common price system afford him.

The manufacturers say that they need stability in the sense that they must have substantial and steady earnings to meet the high overhead charges which the industry has to bear because of its costly capital equipment and expenditure on research and development. We are aware that some of the equipment for making and testing the larger machines, in particular, is extremely expensive and to keep pace with developments in the electrical field a considerable outlay in research is required. At the same time, because much of this machinery is made to order, many of the processes in the workshop cannot be mechanised and the elements of cost attributable to labour and to the drawing-office are also considerable. Our costing inquiry showed that probably about one-third of total cost is represented by indirect wages and other overheads. These overheads are not all fixed costs, but we think that the ratio of fixed overhead costs to total costs is rather higher than in many industries, though not outstandingly so.

*Proposed Modification of the Common Price System.*—We have recorded in Appendix 8 [of the report] a number of modifications of their existing arrangements which the manufacturers told us they would be prepared to consider as additional safeguards to ensure that prices and profits under the common price system were reasonable. These proposals would principally have the effect of relating all common prices to the average of the costs of the lower cost producers which would be determined regularly and accurately with some independent supervision. The manufacturers' proposals do not, in our view, offer any ground for concluding that the common price system could be retained without operating against the public interest.

*Summary of Conclusions : Recommendations.*—We have found that the common price system of the Groups and I.E.A. operates and may be expected to operate against the public interest in relation to the supply and exports of machinery in each of the classes (*a*), (*b*) and (*c*). We have found that the other Group and I.E.A. arrangements we have dealt with in this chapter, except compensation and the arrangements between condenser makers and suppliers of components, operate against the public interest, inasmuch as they support the common price system and that in the following cases they would operate against the public interest in the absence of a common price system :—

(i) The compensation arrangements [for tendering expenses] in relation to the supply and exports of most machinery in class (*a*) and certain machinery in class (*b*).

(ii) The notification [of inquiries and orders] arrangements in relation to the supply of machinery in classes (*a*), (*b*) and (*c*) and also in relation to exports of such machinery in so far as overseas manufacturers participate in them.

(iii) All the differential price arrangements in relation to the supply of machinery in classes (*a*), (*b*) and (*c*) in so far as they are obligatory or involve the listing of individual buyers entitled to allowances, and the arrangement in relation to the supply of certain machinery in classes (*b*) and (*c*) for discounts and rebates based on the aggregation of purchases, or on buying a given proportion of requirements, from a number of manufacturers.

(iv) The protection of arrangements in relation to exports of certain machinery in class (*a*).

(v) The arrangements for common conditions of sale and contract in relation to the supply and exports of machinery in classes (*a*), (*b*) and (*c*) in so far as they are obligatory.

(vi) A number of minor practices in relation to the supply and exports of machinery in classes (*a*), (*b*) and (*c*).

We recommend that all the Group and I.E.A. agreements in which are embodied the common price arrangements which we have found operate, or may be expected to operate, against the public interest should be terminated and that the United Kingdom manufacturers should not in future enter into any agreements or arrangements with one another or set up any other organisation for these purposes.

With regard to the arrangement between the condenser makers and suppliers of components in relation to the supply and exports of certain machinery in class (*a*) we have endorsed the conclusion in an earlier report of the Commission that these should be brought to an end.

We see advantage, as regards both supply and exports of all classes of machinery, in co-operation between the manufacturers in technical matters. We also see advantage in the pooling of market information in respect of exports ; for this reason we find that the notification arrangements for exports would not operate against the public interest in the absence of a common price system, provided that overseas manufacturers did not participate. We also see no objection to recommended model conditions of sale and contract under any of the heads of our reference.

We have not found anything adverse to the public interest arising from the special position of the Central Electricity Authority and of the subsidiaries of Associated Electrical Industries in relation to the supply of machinery in class (*a*).

*Note of Dissent as to Exports by Mr. C. E. Wrangham.*—I am not prepared to say that, in relation to exports the common price system operates against the public interest. General disadvantages of the system are set out in paragraph 769 [of the report]. Loss of one overseas order is recorded in paragraph 787. Some impressions of resentment, felt by overseas buyers, are mentioned in paragraph 788. All these militate in some degree against the public interest. But, on the other hand, the public interest requires that the greatest benefits should accrue and continue from export orders. *Prima facie* this might appear to accord with collective rather than individual policy. The prices and terms that might be acceptable to a certain manufacturer at a certain time, might represent a needless sacrifice of the public interest.

No evidence is available to prove whether collective judgment has in fact been superior to individual judgment or not. But the industry may be presumed to consult its own interest to the best of its ability. Its interests in the export field accord largely with the public interest, namely, to win ever more business on the most profitable terms that are possible and politic. Seemingly, therefore, it is at least concerned—whether or not it may be well qualified—to establish in what manner and by what means the greatest benefits can be obtained from the export trade.

There is evidence that on some occasions the common price system has proved an obstacle in this regard. There is unlikely, in the nature of things, to be direct evidence that it has proved an assistance, but this has clearly been the experience of manufacturers and I find myself with good reasons for sharing their view.

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* Only about one-quarter of machinery in class (*b*) is exported, as against one-half for class (*a*) and two-fifths for class (*c*). In practice a good deal of machinery in class (*b*) which is supplied in the home market is subsequently incorporated in other products, some of which are exported.

† In isolated cases certain manufacturers who are not signatories "co-operate" with the signatories.

# Metallurgical Topics

## Low-Alloy Steels

A FEATURE of metallurgical progress during the past twenty-five years has been the increasing use of low-alloy steels. These steels are continually being improved by modifications of composition and by the application of suitable heat treatment. The first stages of their development were marked by the addition of small amounts of alloy elements (including manganese and silicon) to the carbon steel used for structural purposes. For such purposes, steels for the most part continue to be used in the hot-rolled condition or after a simple normalising; though it has been widely recognised that to get the best properties in many of them a more suitable heat treatment was necessary. With the need for conservation of the alloy elements, increased use has been made of low-alloy steels for constructional purposes and this has emphasised the importance of correct heat treatment to obtain the best possible properties with minimum alloy additions. Both factors in the development of low-alloy steels have been studied at the Institut de Recherches de la Sidérurgie (I.R.S.I.D.) by F. Maratray and G. Delbart.*

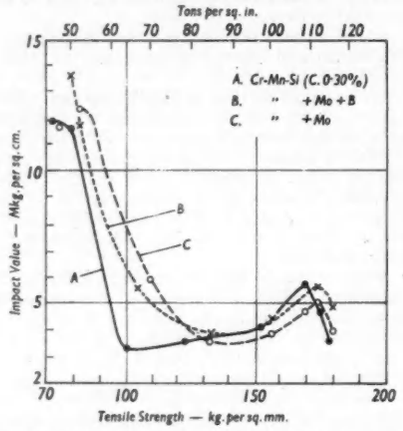



**Fig. 1—Effect of additions to the composition carbon 0·3, silicon 1·3, manganese 1·1, chromium 1·1 per cent on the impact value of the steel, oil-hardened and tempered to give different tensile strengths. (French standard specimen: notch 5mm deep, 1mm root radius)**

### CHROMIUM-SILICON-MANGANESE STEEL

Some years ago these two authors concluded that as a substitute for more highly alloyed constructional steels the best was a chromium-silicon-manganese steel of the type chromium 1, silicon 1·2, manganese 1 and carbon 0·4 per cent. They have now extended their work to ascertain to what extent steel of this basis composition can be improved by small additions of molybdenum, vanadium, boron and elements normally accompanying these additions such as aluminium and titanium. Steels of the above basis composition, but containing 0·25, 0·3, 0·4 and 0·5 per cent of carbon were made in a 300 kg high-frequency induction furnace and cast into 50 kg or 60 kg ingots, to all of which except the first (representing the original composition) separate additions were made. The greater part of the work was done on the two casts containing 0·4 per cent of carbon. The ingots were forged at about 1000–1100 deg. Cent. into bars 18mm round or 12mm square. The bars were heated for thirty minutes at $Ac_3$+50–70 deg. Cent. and quenched in oil, tempered for two hours at temperatures from 200 deg. to 700 deg. Cent. (in steps of 100 deg.), and cooled in air. Isothermal transformation treatments were also applied to some specimens at 50 deg. intervals between 200 deg. and 500 deg. Cent. for four hours (one hour if the transformation was complete in that time), followed by cooling in air. Tensile, notched-bar impact and fatigue tests were made on a large selection of the specimens, and other tests carried out included determinations of Jominy hardenability and examination of micro-structures.

The simultaneous addition of aluminium and titanium caused grain refinement with an increase in hardness, which could erroneously be interpreted as an increase in hardenability. Vanadium alone did not appear to influence the Jominy hardenability curve, but it increased the proportion of martensite at the expense of lower bainite in the oil-quenched specimens. Boron alone did not increase the hardenability, possibly because of the high silicon content, but hardenability was definitely increased by the addition of boron when vanadium and molybdenum were also present. The simultaneous addition of aluminium and titanium increased the impact value slightly on account of the refinement of grain size. Vanadium also caused a slight increase. On the other hand, boron, which was without effect in alloys treated to give very high tensile strength, lowered the impact values corresponding to tensile strengths below 120 kg per square millimetre (76 tons per square inch).

In general, for all compositions, the elastic limit (or rather the load giving 0·01 per cent permanent set) was low in the oil-quenched specimens and increased with increase of tempering temperature, as also did the 0·2 per cent yield strength. The elastic limit was at a maximum and the elongation at a minimum in specimens tempered at 300 deg. Cent. The ratio of 0·2 per cent yield to tensile strength was at a maximum in specimens tempered at 500 deg. Cent. The strain-hardening coefficient was highest for specimens in the oil-quenched condition and very much less after tempering at 600 deg. Cent. This explains the observed fact that the difference in resistance to fatigue measured in a push-pull machine and under rotary bending (in which small deformations may increase the hardness of the surface layer and so improve resistance to fatigue) was greater for steels in the quenched condition than for specimens which had been quenched and tempered.

Steels given an isothermal treatment always had a lower elastic limit and a higher strain-hardening coefficient than hardened and tempered steels of the same tensile strength; and in spite of the more rapid strain-hardening the 0·2 per cent yield strength was also lower for equal tensile strength than in the hardened and tempered steels. When the structure contained both martensite and bainite the elastic limit was always lower than in steels of pure bainitic structure.

Of the quenched and tempered steels, those with 0·25 per cent of carbon showed a minimum impact value after tempering at about 350 deg. Cent.; those with 0·3 per cent of carbon after tempering at 550 deg. Cent.; whilst for those with about 0·4 per cent of carbon the embrittled condition spread over both these temperature zones. In this connection the influence of molybdenum was made the object of special examination. In the steel to which 0·2 per cent of molybdenum had been added, the elongation and impact value, though showing a minor peak after tempering at 200 deg. Cent., remained low for tempering temperatures up to 400 deg. Cent.

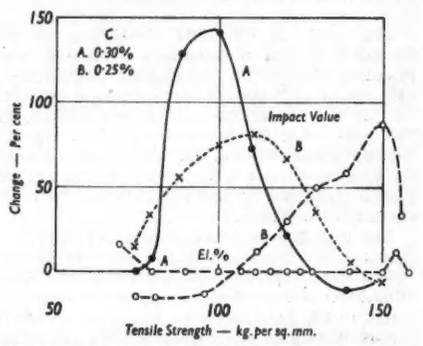



**Fig. 3—Percentage change in elongation and impact value due to the addition of 0·2 per cent of molybdenum to the chromium-silicon-manganese steel of composition given in Fig. 1**

and only began to be satisfactory when the steel had been tempered at above 500 deg. Cent. Impact values for equal tensile strength in steels of basis composition with and without added molybdenum are shown in Fig. 1. After tempering at 550 deg. Cent., the impact value at room temperature of the steels with 0·2 per cent of molybdenum was higher than that of any of the steels without molybdenum. In the steel of basis composition with 0·3 per cent of carbon and 0·2 per cent of molybdenum, tempered at 550 deg. Cent., i.e. to a tensile strength of 100–120 kg per square millimetre (63·5–76 tons per square inch) the impact value is increased by 150 per cent of that of the basis material. Relative effects produced by molybdenum are shown in Fig. 3. With 0·5 per cent of carbon the impact value at equal tensile strength was always lower than with 0·25 or 0·3 per cent of carbon. The effect of molybdenum in counteracting the detrimental influence of high sulphur content on ductility properties (elongation, reduction of area and impact value) is under investigation.

### CHROMIUM-VANADIUM STEEL

The same authors have presented the results of a study of the heat treatment of a chromium-vanadium steel containing carbon 0·43, chromium 1·30, vanadium 0·12 per cent, with special reference to the effect of austenitising temperature on hardenability, structure and mechanical properties. Specimens of the steel were austenitised for thirty minutes at temperatures from 825 deg. to 975 deg. Cent. (in 25 deg. steps), quenched from these temperatures in oil, tempered at temperatures up to 700 deg. Cent. and cooled in air. Fig. 2 shows results obtained with the extremes of austenitising temperatures employed.

A favourable austenitising temperature exists to meet each particular requirement. For example, to obtain good hardenability a high

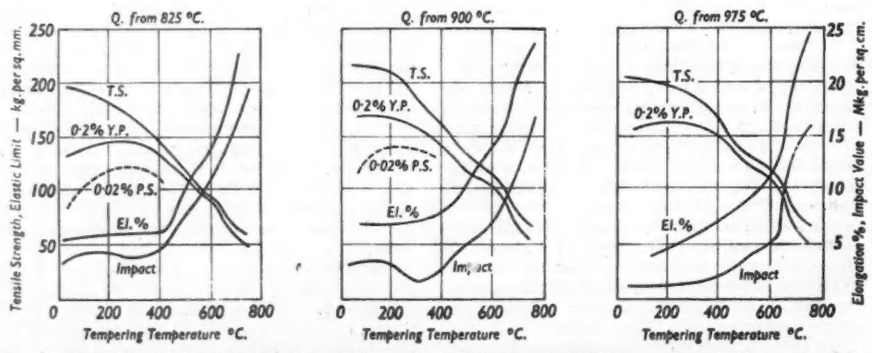



**Fig. 2—Mechanical properties of steel containing carbon 0·43, chromium 1·30, vanadium 0·12 per cent, oil-hardened from different temperatures, tempered and cooled in air**

* *Revue de Métallurgie*, November, 1956, pages 849 and 884.

austenitising temperature is necessary. Raising the austenitising temperature results in progressive dissolution of chromium and vanadium carbides followed by a rapid increase in grain size. The resulting properties depend on these two phenomena. Hardenability benefits from the large grain size. The impact value is adversely affected both by large grain size and by the precipitation of the dissolved carbides on tempering. This fine precipitation of carbide is dependent not only on the temperature but also on the duration of the austenitising and of the tempering treatments. The effect of precipitation of the dissolved carbides, which reduces the softening effect of tempering, is evident after tempering at about 550 deg. Cent. Variations in 0·2 per cent yield strength, impact value and elongation of specimens of equal tensile strength are shown in relation to the austenitising temperature in Fig. 4. For tensile strength over

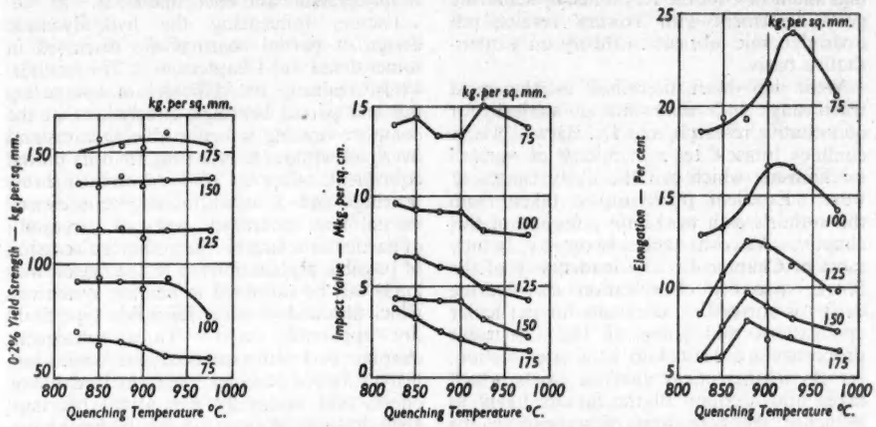



**Fig. 4—Effect of austenitising temperature on 0·2 per cent yield strength, impact value and elongation of chromium-vanadium steel of composition given in Fig. 3, oil-hardened and tempered to give different tensile strengths**

125 kg per square millimetre (79·4 tons per square inch), the most favourable austenitising temperature was found to be about 875 deg. Cent. After this treatment free carbides exist in the microstructure and grain growth is small. For tensile strength lower than 100 kg per square millimetre (63·5 tons per square inch) it seems that an austenitising temperature of 900–925 deg. Cent. should be adopted. In this case quenching retains all the carbides in solution, and probably results in a finer microstructure after tempering, which counterbalances the unfavourable influence of a slight increase in grain size. The effect of the section of the piece treated and of the severity of the quenching must, however, be taken into account in deciding the most suitable time and temperature for austenitising.

## Centenary of the Regenerative Furnace

THE year 1856 was not only marked by the introduction of the Bessemer process, but it was also notable in the annals of the iron and steel industry because, on December 2 of that year, Frederick Siemens took out his first patent for a regenerative furnace. This furnace, constructed in 1857, was, in fact, a coal-fired reverberatory furnace with hearths at both ends, symmetrically arranged about a central chimney, reached through multiple passages of refractory brickwork, which were traversed alternately by the products of the burnt fuel and air for combustion.

This furnace was designed without any intention of using it for steel melting. Frederick Siemens was interested in glass and refractories, but his brother William, also working in London, inspired by an Austrian, Lenz, and possibly incited to further efforts by Bessemer's invention, directed his attention to the melting of steel, an object not attained until some years later. Meanwhile, being a friend of Cowper, he had some part in the design of the regenerative hot-blast stove, the first of which was constructed by Cowper in 1860.

In an article in the November (1956) number of *La Métallurgie*, J. E. Lafon recalls the origin of the regenerative principle and traces the history of the open-hearth furnace and steel-making process throughout the last hundred years. He points out that the first requirement in the development of the furnace was the need to substitute gaseous for solid fuel. Gas producers had been in use in France since 1841, but they gave a poor gas of low calorific power. In 1861, the well-known Siemens gas producer was patented, and its coming into use in the following year constituted a great advance.

The article relates how, after some initial difficulties and misunderstandings, Siemens was allied with the brothers Pierre and Emile Martin, who, in 1864, described their process for steel making in the Siemens furnace. Thereafter, there was steady, though slow, progress, taking somewhat different lines in different countries. Furnaces of 20 tons capacity were in use in 1875. By 1900, the furnace capacity had risen to 50 tons.

The principal stages in the development of the furnace since 1900 are described with references, and diagrams are given of modifications in construction. Present-day problems of design, performance and production are discussed. Finally, regarding the future, five lines of development are suggested as probable: injection of oxygen, extensive use of liquid charges, modification of furnace construction, continuous furnaces, continuous casting.

Progress in furnace design has not been so rapid as, for example, the development of new steels. Whereas materials can be studied in the laboratory and results applied without great difficulty, the thermal conditions in a furnace are subject to "scale effect," which may make experiments on small models misleading. However, apart from the development of instrumentation designed to simplify technique and accelerate operation, various organisations (of which the Comité International de la Flamme receives mention) are now playing an important part in promoting thermal studies which will lead to the increased thermal efficiency of the open-hearth process, to which (the French writer regrets) we have given "so ordinary, impersonal and vague a name."

## Austenitic Chromium-Manganese Steel Containing Nitrogen

A NEW austenitic stainless steel containing chromium 17, manganese 14·5 and nitrogen 0·40 per cent has been developed by the United States Steel Corporation.* The carbon content must not exceed 0·1 per cent. The steel, which goes under the trade name of "Tenelon," is reported to have good hot workability and excellent tensile properties at both atmospheric and raised temperatures. It can be welded by the methods ordinarily used for chromium-nickel austenitic steels; and spot-welding, carried out with one and a half times the force and twice the time used for 18 : 8 chromium-nickel steel, gives welds of greater strength and ductility than are obtained with 18 : 8. Provided that the chromium content is not less than 17 per cent the resistance of "Tenelon" to atmospheric corrosion and to attack by mild acids is similar to that of 18 : 8. In strong acids its behaviour is inferior to that of the chromium-nickel steels, but similar to that of a straight chromium steel containing 16 per cent of chromium.

In the annealed condition the chromium-manganese-nitrogen steel has a 0·2 per cent yield and tensile strength which are considerably higher than those of chromium-nickel 18 : 8 steel and are increased by cold rolling rather more rapidly than in 18 : 8. The elongation is correspondingly lower and is reduced more rapidly by cold working than is the elongation of 18 : 8, as shown by the following figures :—

| | Annealed | | Reduced 35 per cent | |
|---|---|---|---|---|
| | Cr–Mn–N | Cr–Ni, 18 : 8 | Cr–Mn–N | Cr–Ni, 18 : 8 |
| 0·2 per cent yield, tons per square inch | 31 | 25 | 100 | 85 |
| Tensile strength, tons per square inch | 56 | 49 | 87 | 62 |
| Elongation, per cent | 45 | 60 | 8 | 17 |

Short-time tensile tests at high temperatures showed that the properties of the chromium-manganese-nitrogen steel (Tenelon) were considerably higher than those of chromium-nickel 18 : 8, and were similar to those of 18 : 8 steel containing 2·5 per cent of molybdenum. Similar indications were given by the 1000-hour stress rupture tests, results of which are shown in the following table :—

*Stress, Tons Per Square Inch, For Rupture in 1000 Hours*

| At deg. Cent. | 482 | 565 | 649 | 732 |
|---|---|---|---|---|
| Cr–Mn–N (Tenelon) | 30 | 18 | 12·5 | 5·3 |
| Cr–Ni, 18 : 8 | 22 | 14 | 7·5 | 3·6 |
| Cr–Ni, 18 : 8+Nb | — | 19 | 10·3 | 4·9 |
| Cr–Ni, 18 : 8+Mo | — | 19·5 | 10·7 | 5·3 |

The work of Russell Franks and others long ago showed that nitrogen is a strong austenite-forming element and that if the nitrogen content of chromium-manganese steels was increased the rate of cooling necessary to retain austenite was decreased, and, furthermore, that nitrogen (unlike carbon) did not decrease ductility nor reduce resistance to corrosion. Nevertheless, it appears that only restrictions in the supply of nickel have made chromium-manganese-nitrogen steels commercially acceptable. A number of applications are suggested for the new steel, mainly in circumstances in which the chief requirement, apart from adequate strength, is resistance to atmospheric corrosion.

## Molybdenum

THE *Alloy Metals Review* for December 1956 contains the first of two articles on Molybdenum by D. O. Pickman of the Armament Research and Development Establishment. In it he points out that the more conventional alloys can barely keep pace with the increasing demands for high-temperature strength and creep resistance, and that it is therefore necessary to look for other metals on which to base future alloys. Among these, molybdenum metal and molybdenum-rich alloys show great promise for high-temperature applications. Molybdenum production, melting and casting processes are described. The mechanical working of pure molybdenum is said to present no serious difficulties. During hot-working operations, the metal is subject to oxidation and to avoid this stainless steel sheaths and nickel or chromium plating have been used, but it is stated that in the usual operation of forging molybdenum ingots down to bar or sheet without protection the oxidation is not heavy. In the U.S.A. extrusion of molybdenum ingots up to 9in in diameter has been carried out on a commercial scale, glass being used as a lubricant, and this appears to be the most promising method of hot-working molybdenum-rich alloys, but on account of their strength at high temperatures very high extrusion pressures are necessary. After the material has been successfully hot-worked, other finishing processes, such as cold rolling, wire drawing, &c., present little difficulty. The fabrication of molybdenum parts by pressure welding has been shown to be practicable, and some degree of success has been attained in the resistance welding of molybdenum in an inert atmosphere or in a vacuum, but fusion welds are subject to hot cracking. The second article deals with the oxidation-resistance, properties and applications of molybdenum.

* *Materials and Methods*, January, 1957, page 104.

# LETTERS AND LITERATURE

## Letter to the Editor

*(We do not hold ourselves responsible for the opinions of our correspondents.)*

### FLOATING STATIONS FOR NUCLEAR POWER PLANTS

SIR,—Mr. Myers has raised, in a letter in your February 8 issue, the subject of floating stations for nuclear power plant, mainly from the operational point of view. As regards the practicability of designing floating hulls to contain the plant, there would be no difficulty at all in producing a satisfactory design in reinforced concrete, in which a certain amount of prestressing could be used with advantage. The hulls or pontoons could be constructed very much on the Mulberry principle. They would require a considerable draught and their construction would be completed after launching. The pontoons should be considerably broader than shown in the engraving, to give greater stability, more room to move about and to reduce the draught, which might otherwise restrict the number of places in which such a station could be moored.

Owing to the fact that the loads to be carried are heavy and the sites not often of good bearing capacity, a raft foundation frequently has to be adopted. It is not a large step to add the necessary buoyance to a raft so that it is capable of floating in water. When the site is so bad that it must be piled, the foundation work is then so expensive that it might well be economical to consider the floating station.

A. P. MASON, B.Sc., M.I.C.E.
Chief Engineer,
The British Reinforced Concrete
Engineering Company, Ltd., Stafford,
February 21, 1957.

## Literature

**Lubrication of Bearings.** F. T. BARWELL. Butterworths Scientific Publications, Ltd., 88, Kingsway, London, W.C.2. Price 50s.

THIS book is a welcome addition to the very meagre collection of text books on lubrication available in this country. Dr. Barwell has succeeded in condensing into some 300 pages an important proportion of the considerable store of experimental and theoretical knowledge which has accumulated in Britain, Germany and the United States during the past fifty years. His sources include notable pioneers in the lubrication field, significant published papers and the research work of himself and his colleagues in the Lubrication and Wear Division of the Department of Scientific and Industrial Research. The comprehensive list of references to be found at the end of each chapter provides a measure of the unwritten extent of his task. A major part of the text is concerned with thick film lubrication, but the book's real value as a source of reference lies in the balanced and liberal treatment that has been accorded to a range of subjects closely allied to lubrication, such as surface conditions, boundary friction, bearing materials and the design of bearing test rigs. As might be expected in a logical approach, the main subject of thick film lubrication is reached only in Chapter 5, after a stage by stage introduction via the media of surface structure, wear, boundary lubrication and viscosity.

The book opens with a chapter on the nature and structure of metallic surfaces and of their modification by such processes as phosphating, anodising, extreme pressure and corrosion. The major part of Chapter 2 is devoted to boundary conditions but an outline of the three recognised modes of lubrication is included. Earlier theories of Couloumb, Hardy and others are contrasted with the present-day ideas of Bowden, Ming Feng and Rabinowitz. The chapter concludes by describing the now romanticised episode which induced Beauchamp Towers to make his classic experiments on railway axle bearings and how Osborne Reynolds, by achieving good agreement with Towers' results, put hydrodynamic lubrication theory on a quantitative basis.

Wear has been described as the most frustrating and unrewarding subject for quantitative research, and Dr. Barwell wisely confines himself to a summary of various mechanisms which are the likely causes of wear. Excellent photographs, taken from the author's own work, are a feature of this chapter. Viscosity and viscometry occupy most of Chapter 4. The inadequacy of the S.A.E. viscosity classification for bearing design is stressed. Lubricants for particular applications and some of their desirable properties are dealt with in a later section. As no mathematical analysis exists which takes into account all the factors likely to influence the behaviour of a bearing, the theory of hydrodynamic lubrication is rightly introduced by means of a simplified treatment based on Reynolds' original analysis. From this the author derives expressions for frictional drag and load-carrying capacity. A sensible departure from traditional text book procedure is the analysis and design of full journal bearings before partial or thrust bearings are examined in any detail.

Rigorous mathematical treatment is both impracticable and uneconomical for the industrial design of bearings. In any case, idealised design is unnecessary, since bearings are not normally sensitive to very small changes in their environment and are usually built to suit certain existing conditions. What the engineer requires is a design procedure which will predict in advance the performance of bearings in a way which can be readily interpreted and which helps him to assess the relative importance of the variables he meets with in practice. Moreover, the predicted performance should give good agreement with experimental results and rest on a sound mathematical foundation. With this in mind, the "Short Bearing Approximation" of Ockvirk and Dubois is deservedly given considerable attention. This solution facilitates the chart design of many kinds of industrial journal bearings having a length to diameter ratio of one to one or less. The basic theory due to Harrison and Swift governing the behaviour of journal bearings subject to variable loading is discussed in Chapter 12. Although Swift's analysis does provide a picture of the mode in which a journal bearing responds under such conditions of loading, it is important to realise that the theoretical assumptions made endow the lubricant with physical properties which it could not possess in practice. There follows a survey of recent experimental work on journal bearings subject to variable loading and a brief summary of the much discussed but little understood phenomenon of oil film whirl. One of the major difficulties of relating journal bearing theory to the results of experimental research has been the lack of knowledge regarding the extent of the oil pressure film. Recent work by Cole and Hughes in the Mechanical Engineering Research Laboratory has resulted in convincing information which should be most helpful in bringing closer correspondence between theory and practice. In the M.E.R.L. experiments lubricant flow was directly observed in bearings having a glass shell. A striking series of photographs demonstrates the extent of the oil film in bearings having various length to diameter ratios; other photographs illustrate how the film boundaries are affected by changes in oil supply pressure and inlet conditions.

Factors influencing the hydrodynamic design of partial bearings are discussed in some detail in Chapter 10. The author, whilst realising the difficulty of comparing full and partial bearings, concludes that the complete bearing is better able to withstand overload without overheating than its partial equivalent. Chapter 13 is devoted to thrust bearings and a selection of recent experimental and theoretical work is surveyed: of particular interest is the author's discussion of possible explanations as to the reason why loads can be sustained in bearing systems in which film wedges of the Reynolds' type could not apparently exist. Three subsequent chapters deal with aspects of gear lubrication, heavily loaded bearings, elasto-hydrodynamic effects and externally pressurised bearings. Experimental work at M.E.R.L. has shown that reciprocating sliders may, under certain conditions, lubricate themselves by means other than boundary lubrication and in so doing generate high fluid pressures. The author puts forward some tentative explanations and discusses the principles underlying the lubrication of reciprocating sliders and oscillating bearings. Ball and roller bearings are not specifically dealt with. The book concludes with a review of practical arrangements for testing bearings which will be of value to those interested in research. The diagrams and illustrations are of a consistently high standard.

**Engineering Analysis: Survey of Numerical Procedures.** By STEPHEN H. CRANDALL. McGraw-Hill Publishing Company, Ltd., 95, Farringdon Street, London, E.C.4. Price 71s. 6d.

THIS book is of general interest to engineers whatever their particular branch of study as well as to that new race of digital computer programmers. The subject is approached not so much as a survey of mathematical procedures for obtaining numerical results, but rather as a matter of classifying engineering models and the information required from them so as to reduce the engineering problem to one of six main forms for which appropriate numerical enumeration procedures are known, and only then to describe the various transforms, inversions, iterations, &c., available for numerical evaluation. This emphasis on the basic engineering model structure or circuit for the selection of relevant data on boundary conditions and limits is maintained throughout. The standard forms are classed as either systems having a finite number of degrees of freedom or as continuous systems. Both of these are further subdivided into equilibrium problems, eigenvalue problems or propagation problems. These are dealt with in separate chapters.

Each of these six chapters starts out with physical models drawn from a very wide

variety of engineering fields and include, for instance, mechanics, electric networks, wave guide propagation of electromagnetic waves, heat transfer and light spectra. Equations and boundary conditions are stated in relation to these models and the meaning of the solutions when obtained explained in terms of these models. The assistance this gives the engineer in following the mathematics is invaluable. The mathematical procedures for transforming differentiating integrating and partial evaluation are dealt with in terms of matrix notation. Matrix notation, calculus of variations and the theory of characteristics of partial differential equations are fully explained—matters often omitted from engineering courses. The standard of mathematics required to follow these is substantially that of a second-year university engineering student.

This is a scholarly work with adequate references to sources of further information and to reports of special solutions to problems considered more generally in the text. Each chapter concludes with examples or exercises which further advance the application of these principles. Many answers are provided for these exercises. Matrix notation has shortened the text and the brevity this notation affords may beguile readers into thinking that the volume of calculation has also been reduced. Numerical calculation of the examples given in the exercises will, however, soon reveal that the volume of work entailed is almost as great as ever it was. Indications are given as to the appropriateness of special techniques for manual or computer use, but more guidance might have been given in this direction. It is noticeable that most of the post-war advances in this mathematical field (the dates appear from the footnotes to sources, which are generously sprinkled on every other page) are short-cut methods involving skill at selected stages of enumeration, as to the next step, whilst the methods of last century by contrast involve repetitive laborious procedures, but a fixed programme, so making them more appropriate for programming on automatic digital computers, even though entailing more calculation.

The book is based on a series of lectures, and its logical arrangement and generally smooth flow are outstanding, but what a pity that all those flashes of humour that must have enlivened the lectures have been so carefully eliminated. This work represents a useful addition to current literature surveying mathematical procedures by reason of its emphasis on the physical model and is highly commended.

**Directory of Opportunities for Graduates.** Cornmarket Press, Ltd., 1, Lower James Street, London, W.1. Price 7s. 6d.*

UNIVERSITY graduates are in such high demand within many industries to-day that most of them—or at least of those who have attracted the notice of professors—are approached by firms' representatives even before the "formality" of taking a degree examination has been completed. Even if not directly approached they are likely to have made available to them in one way or another pamphlets and brochures of one kind and another produced by industrial firms and descriptive of the works training they can receive and of careers open to them. But all this literature may tend to confuse rather than enlighten. The book before us as we write is therefore very much to be welcomed. It lists a large number of firms, mainly, but not wholly, within the engineering fields and gives concise information about the firms' activities and products, the kinds of graduates that are required, the training that is offered, the location of the works, and, in some instances, the scales of salaries offered. Rather naturally many firms have preferred not to suggest salary scales as so much depends upon assessment of the character and ability of an applicant. Nor, at least for graduates in engineering, who should be seeking practical training rather than employment, do we think that the pay offered should have much bearing on the choice made.

The book has been produced by the publishers with the assistance of an editorial advisory board, consisting of Mr. C. E. Escritt, secretary of the Oxford University Appointments Committee; Mr. E. D. Foster, Editor of *The Director*, and Mr. R. W. Pennock, staff manager of Imperial Chemical Industries, Ltd.

* Free to all final year students at universities and colleges.

**Mathematical Tables: Vol. I.—The Use and Construction of Mathematical Tables.** By L. Fox. H.M. Stationery Office, Kingsway, London, W.C.2. Price 17s. 6d.

THE British Association Mathematical Tables Committee and its Royal Society successor have produced, and the latter hopes to continue to produce, bound volumes, mainly printed in letterpress, of tables of fundamental mathematical functions. In the nature of things this method of publication is slow. Shorter tables, though quicker to produce, are also restricted to tables of fundamental functions of wide application. The Royal Society depository of unpublished tables cannot give rapid and wide publicity for its contents. These and other considerations have suggested the desirability of starting a new form of publication for suitable mathematical tables compiled in the Mathematics Division of the National Physical Laboratory. The N.P.L. Mathematical Tables will be produced by photography from copy prepared with the use of punched cards and a card-operated typewriter. The functions will arise mainly through problems submitted to the Division, so that they will have at least one immediate practical application: forthcoming are tables of Everett interpolation coefficients and of generalised exponential integrals. In this first volume topics are discussed which are relevant to the whole series.

## Books Received

*People at Work.* By John Marsh. Industrial Welfare Society, 48, Bryanston Square, London, W.1. Price 6s.

*Engineering Structural Failures.* By Rolt Hammond. Odhams Press, Ltd., 96, Long Acre, London, W.C.2. Price 25s.

*B.E.M.A. Engineering Directory.* Eighteenth edition. Rankin Brothers, Ltd., Trenchard Street, Bristol, 1. Price 5s. 6d.

*"The Oil Engine" Manual.* Edited by D. S. D. Williams. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 18s.

*Smoley's Four Combined Tables.* By C. K. Smoley. The Technical Press, Ltd., 1, Justice Walk, Chelsea, London, S.W.3. Price 100s.

*Motor Vehicle Mechanics' Textbook.* By F. K. Sully. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 12s. 6d.

*The Cathode Ray Oscilloscope.* By J. Czech. Cleaver-Hume Press, Ltd., 31, Wrights Lane, Kensington, London, W.8. Price 57s. 6d.

*Television Explained.* Sixth edition. By W. E. Miller. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 12s. 6d.

*A Mathematical Tool-Kit for Engineers.* By H. A. Webb and D. G. Ashwell. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 10s.

*Human Relations in Industry.* Rome Conference (January–February, 1956). The European Productivity Agency of the Organisation for European Economic Co-operation, 2, rue André-Pascal, Paris, 16e. Price 18s.

## Technical Reports

*The Trend of the European Gas Economy.* Prepared by the Secretariat of the United Nations Economic Commission for Europe. Obtainable from Sales Section, European Office of the United Nations, Geneva, or through U.K. Sales Agent: H.M. Stationery Office, Mail Order Department, P.O. Box 569, London, S.E.1. Available in English, French or Russian. Price 3s. 6d. or 0·50 dollar.—In its recently published report, entitled "The Trend of the European Gas Economy," the Secretariat of the United Nations Economic Commission for Europe (E.C.E.) states that a substantial contribution to Europe's energy problem could be made by developing the gas industry on a large scale. The advantages of doing so are stated to outweigh the reservations made by the gas industry itself in a number of countries. Gas provides energy in forms readily adaptable to automatic feeding and control devices. The main problems in connection with the expansion of the gas industry, the report says, are to create and operate units, independent from coke-ovens producing gas from coal, brown coal or oil; to combine units of this type with coke-ovens and existing gas works and with natural gas reserves; and to connect these by long-distance transport systems, with large underground storage capacity. Further possibilities described in the report include the transport of liquefied gas and the transport by pipeline of natural gas from oil fields, including the transport of gas from the Middle East. Annexes to the report cover such subjects as net consumption of the various forms of energy in European countries in 1954, gas balance sheets for a number of countries, statistical density of consumers and of sales, and new methods of making gas, such as underground gasification.

*A.E.G. Aus Produktion und Entwicklung*, 1953-1955. Published by Allgemeine Elektricitäts-Gesellschaft, Hohenzollerndamm 150, Berlin-Grunewald. Price DM.11.70.—The book surveys the production and technical achievements of this major German electric concern in the fields of power stations, transmission equipment (some at 400kV), rectifiers and motors of all sizes, and describes the company's approach to problems of higher working speeds, better quality automation and quality control. Increased production means more transport facilities, and AEG has done a great deal in the field of electric rail traction and electric machinery for ships. Much progress has also been made in the design of electric equipment for the home, and for various trades and crafts. A description of the work carried out in the domain of measurements and servo-techniques, and some illustrations of important export orders, conclude the report.

*Practical Guide to the Design of Grey Iron Castings for Engineering Purposes.* Council of Ironfoundry Associations, 14, Pall Mall, London, S.W.1. Price 12s. 6d.—This is an English translation of a French work which is being published by the Council of Ironfoundry Associations as part of its work in fostering closer co-operation between ironfounders and purchasers of iron castings. The book is primarily intended for designers of castings to give them a better understanding of the technical considerations with which an ironfounder is concerned in carrying out instructions. It deals in detail with the properties of grey cast iron; rules for sound design governed by structural factors; design and feeding; and design for reliable and economical moulding. Each particular point is explained concisely, and illustrated by diagrams which show clearly the satisfactory and unsatisfactory points in casting design over a wide field of products.

*Forest Products Research Bulletin, No. 37: "Working Stresses for Structural Softwoods."* H.M. Stationery Office. Price 1s. 3d.—Strength tests on small clear specimens of timber can be used for the purpose of making comparisons between species, but cannot be used directly to give safe working stresses. Grading rules for home-grown softwoods have already been made, and this bulletin shows how working stresses for the two structural grades in the rules can be derived from the results of tests on small clear specimens. The method described takes into account the natural variability in the strength of timber and includes a safety factor. Working stresses are derived for all the strength properties likely to be required in design for nine of the most widely known British softwoods and three of the more commonly used imported ones.

*The Design of Towers, Masts and Pylons.* By D. Bamber, A.M.I.C.E. Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey. Price 3s.—Design methods for the two principal classes of structures considered—free standing and stayed masts—are described in detail in this report. Generally, steel masts only are considered. There is, however, a section on foundation design. Graphical design methods for the superstructures are also exemplified.

# Engineering Education in the Soviet Union

*In the autumn of* 1956 *a team of engineers representative principally of educational establishments in this country visited the U.S.S.R. under the leadership of Professor E. Giffen. The visit was organised by the Institutions of Civil, Mechanical and Electrical Engineers. Early this week, its report was published and we print below the "Introduction" to that report. The remainder of the report goes into much more detail. It is a document that all interested in engineering education should read.*

### The Background of Technological Education in the Soviet Union

THE recognition of the importance of scientific and technological education is deep-rooted in Russian history. Peter the Great was active in the improvement of industrial technique, and Russian scientists have a record of high achievement. Technological institutes were established during the nineteenth century, and after 1917 technological education was stimulated, first, because it is an essential part of Marxist-Leninist philosophy, and secondly, because it was clearly necessary for the rapid economic development of the country. There was already a tradition of technological education, and some physical provision for it, on which the remarkable expansion, planned in the 1930s and revived and extended after the war, could be based.

There is only one employer—the State—which controls the economy through closely estimated five-year plans, in which education and the production of technologists have a part. Because technological education is regarded as of paramount importance, military service is not allowed to interfere with it, or with the subsequent employment of technologists and technicians. The Russian student is not tempted, as are some British students, to go abroad to avoid interference by military service with his professional development.

Rewards of higher pay and better status go to the most able and best qualified. Those who are willing to combine teaching with research or industrial consultancy, and so to bring about the cross-fertilisation of ideas which come from such combined actions, may earn an additional 50 per cent by so doing. Rewards are not confined to industrialists, professors and teaching staff but extend also to students, whose stipends may be raised by 25 per cent for outstandingly good performance. Russia believes that after the survival of the State, higher education is the most important business on which economic and military progress depends, and to ensure that the most able men are employed in higher education, she makes this the best-paid and most socially creditable of all professions. In this respect the Russian scene differs much from that of the West.

Because there was no time to educate the large number of engineers required after the war, some have been allowed to practise without holding a diploma in engineering and without a full formal education. In some branches of engineering the proportion was high in the past, but now it is becoming the exception for an engineer to practise who has no diploma. Engineers do not have to be registered. Those who have no diploma may take evening or correspondence courses and so obtain the necessary qualification. A university graduate with a diploma in physics and mathematics (and possibly others with different combinations of subjects) can practise as an engineer. A physicist may take up design or consulting work in industry. In engineering manufacture, a shop superintendent is required to have a diploma in engineering awarded by an institute, while a foreman is required to have at least a technician's diploma awarded by a technicum.

It is fortunate that a detailed account of the Russian educational system has been published in the useful book on "Soviet Professional Manpower," by De Witt (Russian Research Centre, Harvard University National Science Foundation, Washington, D.C., 1955). We found the statistics relating to engineering in this book to be substantially correct, but the evaluations of engineering in it were insufficient for our purpose and were given in American terms which we have amplified with regard to engineering in British terms. In the present report the descriptions of the Russian educational system have been kept to a minimum on the assumption that the reader who needs a more detailed account will refer to De Witt and other sources.

### Comparisons Between the Russian and British Systems

In Leningrad we visited the Chemical Technology Institute, which we were told is the oldest institute in Russia, having been established in 1828. We understand that it served as a model for the institutes later established in other parts of Northern Europe, e.g. the technical high schools of Germany; and indeed the system of higher education is largely the same in those countries. But the industrial revolution and its technological developments made much less impact on Russia than on the countries of Western Europe, so that until recently her vast natural resources had not even been explored, and are only now beginning to be developed on a modern scale. Finding herself a long way behind in the provision of engineering works of all kinds, and consequently in the improvement of the standard of living of her people, she set herself a herculean task, to build up in the minimum time a great industrial force and to produce the capital equipment needed to exploit her natural resources. Successive five-year plans have called for more power, more steel, more mechanisation and consequently more engineers. After the set-back of the Second World War the tempo was increased, more engineers were needed for the construction of plants and power stations, and as these were completed more engineers could be employed in the plants and using the power; and so the expansion has gone on. Russia is still far behind Western Europe and America in the amount of power available per head of the population, and will not relax until the leeway has been made up. We should look at engineering education in Russia against this background of urgency.

### The Basic Problems of Russian Engineering Education

In any country which is suffering from a shortage of engineers, there are two main problems: finding enough suitable young people for training as engineers, and ensuring that they are properly trained. Any breakdown in the arrangements for dealing with these two problems may have the most serious consequences, and unusual methods may be needed to overcome the difficulties. In Russia the first of these problems, the supply of suitable students, presents less difficulty than it does here, because engineering has been made one of the most attractive careers in the country. Not only is it as well paid as any other, with one exception, but it is highly esteemed as greatly contributing to the welfare of the country. In different ways one receives the impression of a strong faith in the ability of engineers to surmount the many technological difficulties that arise in the development of the country's resources and this faith is already supported by notable achievements. In these circumstances it is not surprising that the engineering institutes have many more suitable applicants than they have places.

The second problem, that of ensuring good engineering training, has two aspects: the staff and the material facilities of accommodation and equipment. In Russia the provision of buildings has lagged behind the growing demand for engineers, but that does not appear to have limited the numbers of engineers accepted for training; where necessary, the institutes work two shifts. As more institutes are built the need for double shifts will become less, but in the meantime the need for engineers has priority over the comfort and convenience of the institutes. The teaching staff are not overworked by reason of the double shifts; additional staff are employed, and we found that the staff/student ratio is about the same as in this country, namely 1 : 10. In some of the institutes the buildings and equipment were not as well maintained as we consider necessary. But the urgent work of training engineers is not allowed to wait for better maintenance.

In the problem of ensuring a sound training for the students, staffing is much more important than buildings and equipment. This is recognised in Russia, and the difficulty of finding staff, not only for engineering but for higher education generally, is reduced but not avoided by making the work financially the most attractive in the country. It was mentioned above that engineering is as well paid as any other career, with one exception; that exception is higher education. The professor is better paid than his counterpart in industry, so those who find that their interests lie in teaching and research need not hesitate on financial grounds. The junior grades also are paid at higher rates than they would receive in industry. We were impressed by the quality of the teachers we met; as at home, some are more interested in teaching than in research, and vice versa, but we found no reason to doubt their ability and enthusiasm.

### British and Russian Intakes

It is not easy to obtain comparative figures for the output of young engineers. The difficulties lie partly in the different categories in which graduates are classified in the two countries, and also, particularly in our own country, in the different routes by which young engineers may reach professional status. In Russia the holder of a diploma from an engineering institute is regarded as qualified to go on, after industrial experience, to work of professional standard. The number of engineering diplomas awarded in 1955 may be taken as 65,000, including architecture and metallurgy, in which the numbers of students are comparatively small. For the United Kingdom we shall take the number of awards reaching the standard that will satisfy the requirements for associate membership of the major engineering institutions. This number includes: the university degrees in the various branches of engineering, including mining and metallurgy; those college diplomas that are treated by the institutions as in the same category with university degrees; and that proportion of Higher National Certificates in engineering which are awarded to those whom experience has shown to be of professional quality. On this basis, our total output of young engineers for the year 1954-55 was about 5000.

When we compare the figures of 65,000 for Russia with 5000 for the United Kingdom, and take into account the ratio of population (about 4 : 1), we see that Russia is training engineers at about three times the rate in this country. But are we right to compare these figures on the basis of population? It may be argued that the production of goods for domestic consumption and for export can be related to the size of the population, and likewise the production of machinery, the building of power stations, and the manufacture of vehicles, but the development of new ideas and of new techniques is different; here the number of workers needed to achieve success in a given time is not related to the size of the population. If the team is not large enough or if their quality is not good enough, someone else will get there first. In this respect we could not be complacent about the numbers of our young engineers, even if they were greater than the Russian figures on a population basis; but they are not even up to that level.

### Future Trends in Intake

The figures we obtained for the intake of students show a very interesting trend. The annual intake of full-time students has reached the desired figure, and according to present plans will remain constant. The intake of evening students, about a quarter of the total intake in 1950, had increased to nearly one-half of the total in 1956 and is expected to increase still further.

This surprised us, as it represents a trend that is just the reverse of that in our own country. Some of the reasons for the Russian trend appear to be :

(i) The output of engineers in 1960 will fill the need, and no great expansion will be required.

(ii) The buildings available are filled to capacity. As new buildings are provided they will be used to relieve the pressure on those institutes which are now working double shifts, and not to increase the number of full-time students.

(iii) As secondary education to the age of seventeen becomes more general (it is to be compulsory after 1960), more students will be seeking admission to the institutes. It will be necessary to offer them some opportunity of higher education, and evening classes will take some of those who do not gain admission to the full-time courses. Consequently, the standard of the full-time students will rise, both in the institutes and technicums.

(iv) Those who complete the evening course for the diploma will be a useful addition to the ranks of the engineering profession. Although the proportion of successes may be relatively lower than for full-time students, those who succeed will be very valuable men.

The situation is very interesting, showing that in Russia the supply of engineers appears to be reaching the saturation point. We have a long way to go before we reach that condition.

### Quality of Education

When we try to compare the quality of the young engineers of the two countries, we are not concerned with the top-grade men—they remain first class in any system of education—we have to consider the lower end of the scale, the standard needed just to satisfy the requirements of the examining body. Such a comparison is difficult to make, but one possible method is to consider the standard of attainment at entry, the examination system, and the proportion who successfully complete the course. Most of our students are selected at eighteen to nineteen years of age, having reached the General Certificate of Education advanced level in mathematics and physics, and in some cases chemistry also. In Russia the selection is made at seventeen to eighteen, and the standard in mathematics and science is one year above our G.C.E. ordinary level. In spite of our students having passed what might be expected to be a good test of their ability to take an engineering course, we find that about 20 per cent may fail at the end of the first year ; in subsequent years the proportion of failures is less. If we were to make our selection from students with mathematics and physics at a lower level we should expect to find that, in spite of having a wider field to choose from, we should make more mistakes in selection, and the number of failures in the subsequent examinations would be greater rather than less. In Russia, however, where the selection is made at this earlier stage, about 87 per cent of those entering the institutes obtain diplomas. On the other hand, if we had 3·6 applicants for each place in our engineering courses, as in Russia, we should expect a smaller proportion of failures. Nevertheless, these figures suggest that the tests applied at the various stages of the course are less stringent than ours, and that some of those who receive diplomas would not have been successful in our system. We reached the same conclusion from a consideration of the Russian examination system and a scrutiny of examination questions ; the short oral examination, taken at the end of each term on the work done in that term and with each subject tested separately, is likely to be less searching and less severe than our system. However, we do not know that our system admits all those who would make successful engineers, or that it excludes all those who would not, and this must remain a matter of judgment based on ample exchange of opinion between those who teach and those who employ engineers.

### Curricula and Syllabuses

We may now turn to the curriculum, the syllabuses and the other elements of the course of study leading to the award of an engineering diploma. The main differences from ours are the younger age at entry ; the longer course ; the greater specialisation in the fourth and fifth years ; and the diploma project as the culminating point and the most important factor in determining success or failure.

Because of the lower age at entry, with a lower requirement in science and mathematics, time is needed during the early part of the course to cover work which our students would already have done. The first two years are widely based and give a good general foundation, the third year covers a fairly wide range of subjects, and the fourth and fifth years are devoted to a detailed study in a specialised branch. During the first two years the student has some training in the college workshops, and during the last three he has a total of about six months' experience in industry. Also, during the first two years, some time is devoted to a foreign language and general studies. Compared with this country, the lower attainment at entry in Russia, the wider range of non-technical studies in the first three years, and the narrow specialisation in the last two, all point to the conclusion that the student in Russia does not proceed as far in as wide a range of fundamental engineering subjects as the corresponding student here. However, he has gone much farther in the technology of a particular special subject and might have carried out a design project under a practising engineer, and, at the end of his longer course, is ready to take his place in industry as a member of a design office, in a team of development engineers, or in a junior executive post.

The comparison of the relative merits of the two systems of training must not be made at the point where the young people are graduating. The Russian graduate, after his 5 or 5½-year course in the institute, when his age is twenty-two or twenty-three, should be compared with our graduate towards the end of his training in industry. If—and here is an assumption to which we shall return later—this period of industrial training is intelligently planned and used, our graduate will be as well versed and as competent in the technology of his chosen speciality as his Russian counterpart ; and the wider range of his fundamental subjects gives him a degree of flexibility that is advantageous in our industrial conditions.

### Practical Training

Practical training in industry is generally regarded here as essential for an engineer. An engineering graduate here is not a finished product, as in Russia and other European countries ; he is only partly trained when he leaves college, and must finish with a suitable period of training in his chosen field. In Russia the practical training occupies 200 to 300 hours in the workshops of the institute and three periods of two months each in industrial works. The Russian student gains some elementary experience in the use of tools and machines in the institute's workshops ; in industry he works not on the shop floor as would be our practice, but as assistant to another engineer, sometimes in a junior managerial position. This practical training being an essential part of the course, is supervised by a member of the staff who remains at the works during this period of industrial experience. The Russians, in re-examining their system, have said that they propose to make a change which will require two years of suitable experience after completion of the 5 or 5½-year course, and before the award of the diploma. It will be interesting to see the reaction of Russian industry to these proposals, which would delay the availability of qualified men but probably give them a better man in the end. Recently in this country we have been re-examining our ideas about the best way to organise the practical training of our young engineers. The systems in Russia, in other European countries and in America are significantly different from ours. This does not necessarily mean that ours is wrong, but we must satisfy ourselves that the longer period given here to this side of an engineer's training is justified by the results and is used economically.

When we try to sum up on the quality of the engineers being produced by the educational systems in Russia and Britain, we see that in Russia the student is trained to take an active part in a specialised branch of engineering as soon as he completes his course. In particular, the training in the latter part of the course, with its emphasis on design, gives him a leaning in this direction, a feature which many employers in this country must envy. Our young engineer, who enters the industry through a degree or diploma course and industrial training, will have covered a wider range of subjects at an advanced level, and, after his training in industry, should be as good in his specialised line as the Russian. We think that our system produces a man who will find it easier to apply his knowledge to new problems, and indeed to switch from one kind of engineering to another. Our young graduates need not choose the direction of their specialisation until they have completed both the academic part and at least half of the practical part of their education and training, when they are better informed and experienced for making the choice than they would have been at an earlier stage.

Our young engineer who enters industry through sandwich diploma courses, will, it is hoped, have enjoyed a training in which the academic and industrial parts will be closely combined. As this is being done in various ways, and this type of course is still being developed, it is impossible to make a useful comparison yet with the Russian system. The National Certificate part-time day courses make a substantial contribution to the supply of engineers in the United Kingdom, for the upper fractions of the Higher National Certificate holders continue their studies and secure professional qualification. This intake has steadily increased in numbers, and in 1954-55 it provided 2800, or 56 per cent of the total of qualified engineers. Thus we have three distinct streams of entry which have grown out of our social and economic conditions, and are flexibly related to the variety and changing character of our economy.

The flexibility which characterises our system is more necessary here than in Russia. We have to strive to keep in the forefront of technological progress ; our exports depend on it. In efficiency, we must seek the last fraction and be ready to seek and use unorthodox methods to achieve it. In Russia the economic conditions are quite different ; also, their system gives quicker response to changing needs of industry for engineers trained in the many different specialities. Hence any engineer may expect to find employment in his specialised field, and the question of switching from one field to another is less likely to arise. We are of the opinion that the main framework of our system of education and training suits our conditions, and we saw nothing to suggest that the Russian system is not equally suited to theirs. But this is not to say that either system is incapable of improvement. Indeed, the Russians are examining their arrangements with much the same urgency and concern as we are giving to our own.

### Employment of Women in Engineering

One of the most significant differences between Russia and the United Kingdom is in the attitude to the employment of women and the number of women students in engineering courses. In Russia, women are employed in all kinds of work and not only in those occupations in which they have an accepted place in the United Kingdom ; even in heavy work such as building they can be seen mixing mortar, laying bricks and working on the erection of scaffolding ; they drive trams and buses, sweep streets, and so on. They take a large part in higher technology, in which about half the students are women, and in some branches their numbers as students considerably exceed those of the men.

The situation is very different in the United Kingdom, where the woman engineer is still an exception, and neither public opinion nor the social and economic organisation of the country has adjusted itself to the idea of, and provision for, the large-scale employment of women in advanced engineering work ; the result is that few girls think of engineering as a desirable career. But in Russia the girls are as keen to become engineers as the boys, with whom they compete on level terms, both in the entrance examination and as students. We believe that many of our girls are potentially just as capable in engineering as boys, but are not attracted to it, partly by custom and a feeling inherited from the past that engineering is socially less creditable and less suited to women than are other careers,

and partly through ignorance of the opportunities which engineering offers to-day. But the times have changed, and so has the nature and content of engineering, and there are many jobs that woman could fill with distinction, and in which they would find a satisfying career in a socially satisfying environment.

The training and employment of women as higher technicians is relatively easy, even when their period of service is comparatively short ; but full professional education and training is a costly business, and when it is likely to be interrupted for the family its arrangement, in our free economy, presents some challenging problems. It will be necessary to attract professional women back into industry when the children have grown up, and to provide refresher courses for them on their return. What we saw in Russia suggests that in this country a potential source of an increased supply of good engineers is being neglected.

### Research and Industrial Contacts

In our brief visit we were mainly concerned with the undergraduate work of the engineering institutes, but we saw enough of the research work in progress to form a high opinion of it. Teaching staff, research students and full-time assistants were occupied in a wide range of researches, in most of which the close contact with industrial needs was very evident. In Russia, where the later part of the course is concerned with the teaching of specialist techniques, the view is strongly held that engineering teaching at a high level can only be successful if the academic staff are at the same time actively engaged in extending their knowledge and experience, as by research and industrial consultancy. Research is financed on an impressive scale, and the academic staff may augment their salaries by 50 per cent by engaging in this kind of work. This is at variance with the practice here, where, for example, some Government Departments in their research contracts with universities will not permit the academic staff concerned to receive payment for their services.

One of the interesting differences between the two systems is in the organisation of higher education. The Russian Ministry of Higher Education collects information from other ministries about their requirements for young men and women with different kinds of training, and it is the responsibility of the Ministry to plan its operations to meet these requirements and also to foresee any developments that are likely to modify the figures given by the other ministries. Not the least surprising difference was to find that the Minister of Higher Education is himself a professor in one of the engineering institutes, and also that the heads of various sections in the Ministry are professors and senior teachers—all active in their teaching work alongside their duties in the Ministry. We were very much impressed by the complete grasp of all sides of the problems of higher technological education shown by the Minister and his colleagues. This close relationship between teaching and administration is in marked contrast with our system.

The system of engineering training in Russia encourages close contacts between the teaching establishments and industry, partly because of the more specialised nature of the courses. The teachers in the specialised subjects have had extensive industrial experience, or come from industry as part-time teachers. The research in the institutes is closely concerned with industrial problems and necessitates close contact with industry. Also, the industrial training which is a necessary part of each student's course requires him to spend three periods of about two months each in industrial establishments. The difference here between the two systems is that this industrial work must be satisfactorily completed before the student can qualify for a diploma, and also that it is done under the direct supervision of a teacher from the institute, who goes to the works to supervise the students. It is generally agreed that close relationship between education and industry is valuable to both, but the arrangements for promoting this close relationship appear to be more effective in Russia than they are here.

The Ministry of Higher Education, being responsible for obtaining as well as training a sufficient number of good students in each of the many specialised branches of science and engineering, arouses the interest and stimulates the enthusiasm of boys and girls by sending its representatives to schools to give lectures and to show films, explaining the opportunities in newly developing fields. The Ministry also offers incentives in such ways as hostel accommodation for those living away from home, high stipends for those taking the less popular courses (and these stipends are paid irrespective of the financial circumstances of the student or his parents), and a 25 per cent increase in the stipend for excellent progress. These active measures, together with the high status of engineering as a profession, ensure keen competition for places in the engineering institutes. In the United Kingdom the response to changes in the demand for engineers of various kinds is slow, and there is a danger that the fluctuations in the supply of engineers will get out of step with those in the demand, which would discourage recruitment and increase the effect of time lag.

# Scientific Investigation of the Upper Atmosphere

THE first " Skylark " upper atmosphere rocket was fired at the Woomera Rocket Range on February 13, 1957. It was the first firing in a series of tests and no scientific observations were made.

Five university groups working under the auspices of the Gassiot Committee of the Royal Society, and the Royal Aircraft Establishment, are co-operating in carrying out scientific investigations using instruments carried to high altitudes in the atmosphere by " Skylark " rockets.

It is of basic importance to measure the temperature, pressure and density of the atmosphere up to the greatest attainable heights. In the same category can be included the study of the variation of wind speed and direction with altitude. The group at the Physics Department of University College, London (Professor H. S. W. Massey, F.R.S., and Dr. R. L. F. Boyd) are proposing to measure the temperature and horizontal and vertical wind speeds up to heights of 60 miles or so using a sound ranging method: this is based on the following principles.

The speed of sound in the air is proportional to the square root of the air temperature, so that from the observed variation with height of the speed of sound, that of the temperature may be obtained. Grenades will be ejected from the rocket at regular intervals to explode after about two seconds. The arrival of the sound pulse from each explosion will be timed at an array of ground-based microphones. At the same time, the arrival of the flash from the explosion will be observed on several wide-angle cameras, also on the ground. From analysis of the data, using electronic computation, it is possible not only to obtain the required variation with height of the speed of sound, but also to determine the deviation of the downward-moving sound waves by the winds at different heights.

Experiments proposed by the Royal Aircraft Establishment are aimed at the determination of air pressure density and temperature from readings of pressure gauges mounted on the nose of the rocket itself.

The wind distribution will also be studied by a group from the Meteorology Department at Imperial College, London (Professor P. A. Sheppard), using a different method. A cloud of radar-reflecting aluminium strips will be ejected at about 30 miles' and 50 miles' height. The movement and spread of the cloud, under the influence of the winds, will be followed by radar as it falls.

There are a number of remarkable optical phenomena associated with the upper air. One of these, the polar aurora, is fairly well known, but there is a far more constant and usual sky emission called the night air-glow. On a clear night the light from the sky includes not only the sum total of starlight and any moonlight, but also this faint component which is emitted from the atmosphere itself. Although this air-glow has been studied for a long time, the nature of the processes which give rise to it are far from well understood and even the heights from which the strongest emission of the different wavelengths are emitted are not known. The group at Queen's University, Belfast (Professor D. R. Bates, F.R.S., and Dr. E. B. Armstrong), is to fly instruments designed to measure the intensity of the light from the night air-glow at different heights. Certain wavelength ranges for study will be selected by suitable filters and the light intensity measured by electrical methods. These will be transmitted to ground by a coded radio signal, during the rocket flight.

An unexpected constituent of the light in the night air-glow is the yellow light of sodium. It appears that there is about 1 ton of sodium in the higher atmosphere, and it is by no means clear why these metallic atoms should be present and no others. The brightness of the yellow sodium emission is much greater at twilight and dawn. This is because the sunlight which is not visible at ground under these conditions, causes the sodium, which is concentrated about 45 miles up, to fluoresce strongly. The Queen's University group propose to produce sodium yellow fluorescence artificially by ejecting a cloud of sodium at a chosen height from a rocket. This will be done, as in the first American experiments which were undertaken following a suggestion by Professor D. R. Bates, by carrying in the rocket a mixture of sodium and thermite which is ignited and ejected from an enclosing canister and thrown out. If the rocket flight is carried out at twilight the ejected sodium cloud will glow a bright yellow. By following the motion of different parts of the cloud, information can be returned about wind at the cloud height. This can be done by using the same cameras as those employed by the University College group for the grenade experiment. Furthermore, the temperature of the region occupied by the glowing cloud can be obtained by studying the widths of the sodium spectrum lines emitted. Spectroscopic studies of the glow will also help in the understanding of the different chemical processes which contribute towards the air-glow emission.

The region of the upper air known as the ionosphere plays a vital part in securing the transmission of radio signals to great distances over the earth's surface. These signals would pass straight out into space without following the curvature of the earth if it were not for the ionosphere which reflects them back to ground, provided they are not of too short a wavelength. The main regions of the ionosphere are the E layer (about 60 miles up) and the two F layers, which extend upwards from an altitude of 100 miles. These layers are effective because they contain important concentrations of free electrons and charged atoms or ions. Much information has been obtained about the layers using radio signals, transmitted and received at ground, as probes, but some information can only be obtained by using rocket-borne transmitters and receivers. Plans are being made to carry out studies of this kind by Dr. W. J. G. Beynon, of the Physics Department, the University College of Swansea, and Mr. G. Ratcliff, of the Department of Electrical Engineering, the University College of Swansea, in conjunction with the Royal Aircraft Establishment. Assistance is also being afforded by the Royal Naval Scientific Service in the provision of apparatus.

These radio experiments give information about the variation of free electron concentration with height. They require extensive equipment and much preliminary testing so that the final measurements will not be made till a somewhat later stage in the programme than the other investigations. On the other hand, equipment to obtain information about the ionosphere without use of radio signals will be flown in the rockets by the groups at the Physics Departments of the

University of Birmingham (Professor J. Sayers), of University College, London.

It is the object of the latter experiments to determine not only the degree of ionisation, but also the actual types of ion present in the ionosphere. To do this, the ions will be collected by equipment ejected from or projected out of the rocket, and capable of analysing the ions to determine their mass and whether they are positively or negatively charged. The results, suitably coded, will be returned continuously to ground by the radio telemetry link as the rocket ascends through the layers. All the experiments described above will form part of the United Kingdom contribution to the International Geophysical Year (July, 1957, to December, 1958), which is being organised by the Royal Society.

## Large Mechanised Foundry and New Machine Shop

AN extensive programme of reorganisation and mechanisation has just been completed in one of the foundries of Beans Industries, Ltd., Tipton, Staffs, and a large new machine shop has also recently been opened. This firm has two foundries, the smaller one of which was mechanised some years ago and is now producing castings weighing up to 150 lb, at the rate of about 120 tons a week. The larger foundry, which has now been mechanised, is equipped to produce castings weighing up to 6 cwt and is designed for an output of about 600 tons a week on single-shift working.

The whole of the new mechanised installation is designed to reduce manual effort on the part of the operators to a minimum, and enable a close control to be maintained over casting quality at all stages of production. The general flow of production is down the length of the foundry, and the main core-making section is concentrated at the top end. Here the core-making machines and benches are supplied with sand by overhead bins fed from sand drying and preparation equipment. The cores are taken by a pendulum conveyor system to the drying ovens, and then from the ovens to storage racks adjacent to the mould closing stations.

The main floor is divided into two mechanised sections, one for green and the other for dry sand moulding, each being served by a pallet conveyor system working on a closed circuit. The normal sequence of cope and drag making, coring, closing, pouring, cooling and knock-out is followed in the green sand section. In the dry sand section the copes and drags are dried in large ovens and stored on a series of roller conveyors, where they are cored and closed, before transfer to the pallets for pouring, cooling and knock-out.

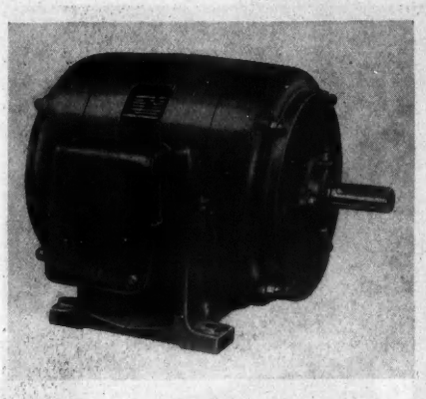
At the knock-out stations the hot castings are transferred to an overhead conveyor system, which carries them through a large cooling enclosure and a core-removal station before they are returned to the main shop floor. The castings are removed from the conveyor at a "Wheelabrator" station for final cleaning. From this station the castings pass into a fettling and trimming area and then through inspection lines before final release to a despatch section. All of the sand recovered through an underfloor conveyor system is treated in a reconditioning plant and returned to the moulding stations by overhead conveyors. The foundry is served by eight cupolas, which are fed from stock bins, arranged in a semi-circle for speedy batching and supplied from an adjoining main bin installation by overhead cranes.

The new machine shop of the firm covers an area of some 250,000 square feet, and has been laid out for batch production work of light and medium character, such as gearboxes and engines. The facilities available include a design office, toolroom, welding shop, and test and assembly areas, so that the firm can undertake a complete batch manufacturing programme from the design stages right through to the finished assembly of an individual product. A comprehensive range of machine tools has been installed and provision has been made to enable special groupings of machines to facilitate flow batch production on any individual component should the demand warrant such a measure.

## Drip-proof Squirrel-Cage Motors With Class-E Insulation

A NEW range of drip-proof motors from ½ h.p. to 50 h.p., complying with the draft British Standard CW (ELE) 6246 and having Class-E insulation to permit a temperature rise of 65 deg. Cent. has been introduced by Newman Industries, Ltd., Bristol.

The development of this range marks a change in policy, inasmuch as the company has hitherto favoured the universal use of totally enclosed motors. This policy was based on the fact that British Standard Specifications permitted temperature rises of 50 deg. Cent. for totally enclosed compared with only 40 deg. Cent, for drip-proof motors. By taking advantage of the 10 deg. difference permitted by these specifications the company contended that the benefits of



**Drip-proof motor with Class-E insulation for 65 deg. Cent. temperature rise**

complete protection inherent in totally enclosed machines could be offered at little extra cost, the prices in some cases being competitive with those of drip-proof machines.

With the advent of a draft British Standard covering ventilated motors with Class-E insulation permitting a 65 deg. Cent. temperature rise the 10 deg. Cent. advantage formerly possessed by totally enclosed motors was lost. The draft B.S. No. CW (ELE) 6246 standardises for the first time the dimensions of three-phase motors with ventilated enclosure. An important provision of the new draft dimensional specification is that it covers motors built to the amended B.S. 2613 (electrical performance), incorporating Class-E insulation, which permits a maximum motor temperature rise of 65 deg. Cent. under continuous maximum rating condition. The existing electrical specification for drip-proof motors, B.S. 168, specifies Class-A insulation, which permits a maximum motor temperature rise of 40 deg. Cent. but allows for sustained overloads. Basically the new draft specification means that a greater output can be obtained from a given motor frame size; alternatively, a given horsepower can be developed by a smaller, lighter motor.

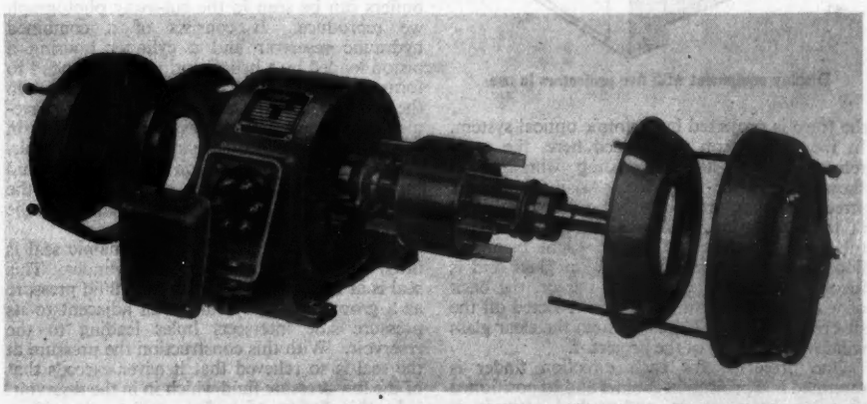
To produce a simple squirrel-cage motor to comply with the new draft specification, Newman Industries, Ltd., has laid out a new production line at its factory in Yate, Bristol. In the new design of motor the main innovation, apart from the use of Class-E insulation, is in the ventilating system. As can be seen from the accompanying illustrations, rectangular-shaped vents are provided in the base of each endshield. These openings admit the cooling air, which is forced, by fans at each end of the rotor and by light alloy deflectors, to flow over the bearings and then between the stator frame and core, before being expelled through protected vents in both sides of the stator frame. One of the outlet vents can be seen below the terminal box in the accompanying illustrations. A subsidiary function of the air deflectors is to give protection to the winding end turns; no screen protection is normally provided over the ventilation openings.

The stator frame is a one-piece normalised iron casting produced in the company's own foundry to ensure a close control over casting quality. Each stator core is prebuilt from low-loss silicon steel sheet, and accurately machined on inner and outer diameters to ensure a correct and concentric air gap. In the smaller stators the bores are finished to dimension by broaching.

In the stator windings the coils are preformed and wound with synthetic enamel covered wire, the wire being based on polyvinyl formal. The slot insulation consists of a thick leather paper covered on one side with cellulose triacetate to give an insulation with a high dielectric and mechanical strength and high resistance to moisture. A thick triacetate-covered leather paper separator is also placed between the coil sides in the slot and two thicknesses of the same material are inserted between phase groups in the end winding. Sleeving, where it is required on the end turns, is of impregnated "Terylene." The completely wound stator is immersed in thermo-setting insulating varnish and then baked to render it resistant to moisture.

The rotor cores are assembled from stampings of the same material as that used for the stators. The squirrel-cage "winding" is die cast around the core in aluminium, integral with a cooling fan at each end, as illustrated. The core is shrunk on to a steel shaft.

The end brackets are grey iron castings and they can be turned so that the ventilating air enters from the top, to give drip-proof protection when the motor is ceiling mounted. Grease nipples and relief plugs are fitted. The shafts run in ball bearings, which are of standard metric sizes and are lightly preloaded to reduce noise. At the non-driving end the shaft is retained axially in the bearing by a snap ring. On the standard foot-mounted motor the terminal box is on the horizontal centre line and is fitted on the left-hand side viewed from the driving end, but the position can be changed to the right-hand side by reversing the stator. Two screws secure the terminal box lid; the cable outlet can be set at four positions at intervals of 90 deg. and the screwed conduit gland is detachable. The stator leads are brought out



**Drip-proof squirrel-cage motor, with Class-E insulation, dismantled to show main assemblies. There are openings for cooling air at the base of the endshields and on each side of the frame near the mounting feet. The cooling air path is partly determined by a deflector inside each endshield**

to brass terminals mounted in a moulded block, with engraved terminal markings.

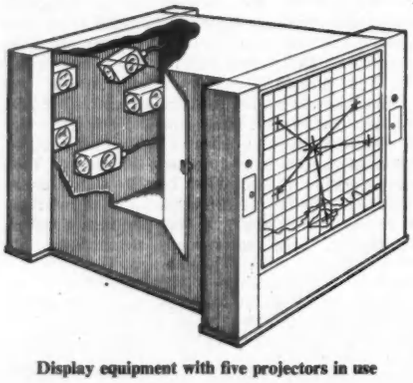
The Newman range of motors covers continuously rated outputs from ¼ h.p. at 750 r.p.m. to 50 h.p. at 3000 r.p.m., and the windings (three-phase, 50 c/s) are designed for a maximum of 650V.

## Automatic Position Plotting

A SYSTEM of automatic triangulation of a number of bearings in order to establish the position of an aircraft with negligible delay has now been installed by the Royal Navy at Yeovilton, near Yeovil, and Abbotsinch, near Glasgow. The information is derived from the automatic direction finders normally installed at R.N. Air Stations, which display the bearing of an aircraft on a cathode-ray tube while the appropriate frequency on the pilots' v.h.f. radio-telephone is transmitted. The bearings from all the stations—five, including Yeovilton, on the Southern Fixer—are telemetered to the central control and appear instantaneously on a map of the area. An operator can then observe the position of the aircraft and report it to the pilot.

A noteworthy feature of this equipment, which was supplied by Standard Telephones and Cables, Ltd., is that the information does not need a coaxial cable for its transmission, but can be passed along a G.P.O. telephone line, through carrier equipment, or over a radio link. The bearing information is imposed upon a 1020 or 2220 c/s carrier in the form of frequency of keying. "Phantastron" circuitry at the receiving station decodes the rate of keying to give the ratio of the voltages upon $x$ and $y$ plates in a cathode-ray tube to generate the original bearing on the tube face.

High-intensity tubes similar to those used by projection television receivers are employed, and the trace is projected by a simple optical system. In the photograph reproduced here, the tube, removed from its surrounding windings, is shown beside the projector. An inclined glass screen, running from top left to bottom right in the illustration, is silvered except where the tube faces it near the centre. Light from the fluorescing tube passes through the glass and is focused by a circular concave mirror, the back of which can be seen. It is then reflected off the silvered screen and leaves through the clear glass window on the top of the projector.

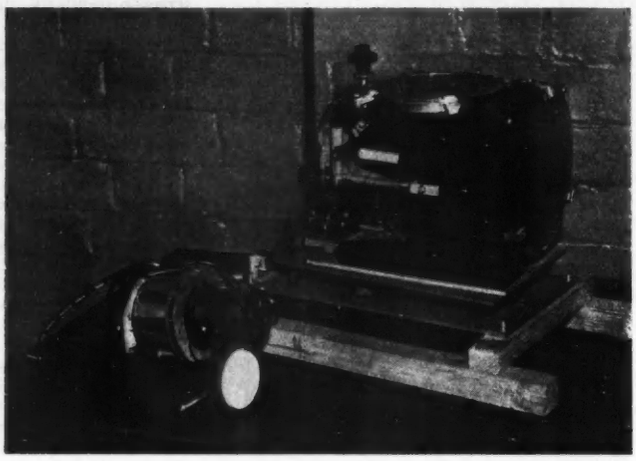


Display equipment with five projectors in use

One projector for each direction finder is mounted in a projection cabinet and so positioned that the beam in its undisturbed attitude is directed at the position of that direction finder on the map engraved on a ground glass screen. Thus when a bearing is generated by the tube, a line of position appears on the map; the intersection of two or more lines fixes the transmitter.

The display unit can carry as many as ten projectors behind a 60in square screen, or eight with a 40in screen. The accuracy of the telemetering equipment is claimed to be effectively perfect; errors are lost in the thickness of the lines. The telemetering channel, besides giving bearings to the centre, gives three further facilities; it can control up to six on/off switching functions at the outstation; for testing or other purposes, it can give telephone communication between centre and outstation, and it can relay transmissions between aircraft and centre.

The equipment demonstrated to us at Yeovilton is believed to have been the first example of automatic triangulation. Besides the two R.N. fixers, which cover the greater part of the United Kingdom, the Royal Air Force is to establish five stations at Uxbridge, Watnall, Gloucester, Preston and Prestwick, which will provide a position-finding service for international air traffic. Two systems are also to be installed in the Netherlands and one in Belgium.



A projector unit with the high intensity cathode-ray tube and its control coils separated

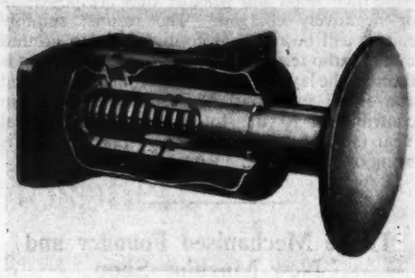
## Hydraulic Buffers for Railway Stock

A HYDRAULIC buffer for railway stock which has been developed by Dowty Hydraulic Units, Ltd., Arle Court, Cheltenham, Glos, is stated to have more than twenty times the shock absorption capacity of conventional equipment. These buffers have a small number of working parts to minimise the need for maintenance, and they are suitable for all types of freight wagons and diesel rail cars. Of compact, self-contained design, they are readily fitted in place of conventional buffers. They are available with projections of 1ft 6in, 1ft 8½in, 1ft 10in, and 2ft, with a corresponding range of head sizes to provide for standard requirements.

The general construction of one of the new buffers can be seen in the cut-away photograph we reproduce. It consists of a combined hydraulic reservoir and a cylinder housing a piston loaded by a helical spring and extended to form the buffer head. On impact the fluid in the cylinder is displaced by the inwards movement of the piston and flows through orifices in the cylinder wall into the surrounding reservoir. The restriction imposed on the flow of fluid through the orifices causes a back pressure in the cylinder which reacts on the piston and gives the buffer its resistance to closure.

It will be seen that only one dynamic seal is fitted between the piston and the cylinder. This seal is at no time subjected to high fluid pressure as a groove in the cylinder wall adjacent to its pressure side intersects holes leading to the reservoir. With this construction the pressure at the seal is so relieved that it never exceeds that of the low pressure fluid which in in the reservoir.

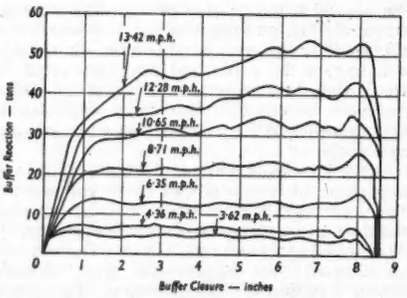
In this design of buffer, unlike one with a mechanical spring which provides a fixed resistance for any given closure, the reaction is related to the speed at which it closes. Due to the square law governing flow through orifices, the pressure generated in the buffer is directly proportional to the energy to be absorbed. Consequently, the buffer is self-adjusting to changes in impact energy resulting from variations in wagon velocity. Violent recoil is obviated by its design principle of energy dissipation and not energy absorption. Impact energy is converted into heat energy as the buffer closes, and the small quantity of air trapped in the reservoir is compressed slightly as the displaced fluid flows into the reservoir. On completion of the closing movement, the bulk of the impact energy has been dissipated and the recoil is controlled by the combined effects of the load in the recoil spring and the air pressure.



Construction of hydraulic buffer consisting of a combined hydraulic reservoir and cylinder in which there is a spring loaded piston extended to form the buffer head

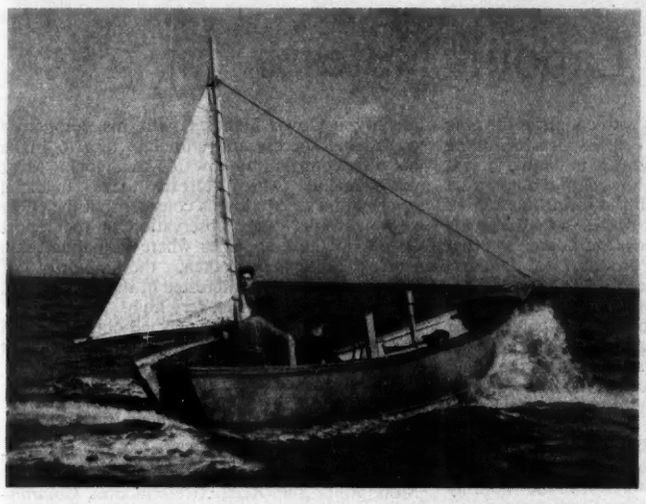
The immersion of the recoil spring in the hydraulic fluid fully protects it against corrosion and the piston is protected by chromium plating. The fluid capacity of the buffer is approximately ten pints, although only eight and a half pints are needed to keep the pressure cylinder full. The adequacy of this reserve of one and a half pints has been confirmed by tests which indicated a fluid loss of only 70 c.c. after 5000 heavy impacts.

The makers point out that the new buffer adjusts itself to meet a range of wagon weights and speeds, providing very little more than the reaction theoretically required to bring about the required change in velocity within the available travel. This performance is made possible because the reaction of the buffer is proportional to the square of the closure velocity and the kinetic energy of the wagon is also proportional to the square of its impact velocity. In effect the buffer provides a soft cushion which is all that is necessary at low speeds, but stiffens to meet the needs of higher shunting speeds.




Reaction/closure curves for impacts between hydraulic buffers on wagons of 24 tons rolling weight

The performance curves for Dowty buffers fitted to wagons of 24 tons rolling weight impacting at speeds between 3·5 and 13·5 m.p.h., which we reproduce, indicate how quickly a high initial reaction is developed and how nearly constant the reaction remains until the end of the buffer closure. The uniformity of the retardation provided by the buffer is apparent and the general similarity between the curves given illustrates the consistency of the buffer's performance over a very wide range of shunting speeds. It is stated that the reaction during impacts between hydraulic and spring buffers is somewhat greater than in the case of impacts between two hydraulic buffers, but it is still many times less than that encountered by two spring buffers under the same conditions.



Fishing boat for Nigeria undergoing trials, and (right) completed hull showing twin skegs and stern gear

## Aluminium Alloy Fishing Boat

RESEARCH into the ways of increasing food is one of the activities of the Food and Agriculture Section of the United Nations Organisation, and one aspect of this work is the endeavour made to improve fishing methods and equipment. This is of importance where there are ever-expanding populations in maritime countries and particularly so where there are no natural or man-made harbours, so that boats have to be handled from beaches. Additional difficulties have to be overcome when operations are hampered by heavy surf and breakers often 5ft in height, such as obtain on the coast of Nigeria.

For many generations Nigerian fishermen have used " dug-out " canoes which they have been able to launch and beach through the surf under reasonable climatic conditions, but which are suitable to meet the demands of fishing on a greatly increased scale. The position called for special measures, and Brooke Marine, Ltd., Lowestoft, at the invitation of the Crown Agents for Overseas Governments and Administrations, on behalf of the Nigerian Federal Fisheries Service, designed and built a prototype boat suitable for working under such conditions. In the construction of this craft special consideration was given to producing a light but robust hull at an economic price, and the constructional methods adopted were the result of discussions between the builders, Northern Aluminium Company, Ltd. Aluminium Laboratories, Ltd., and Aviation Development, Ltd. Reports of the proving trials indicate that the prototype was successfully launched and beached and handled perfectly through the surf.

As built, the boat, which can be seen undergoing trials in our illustration, has a length overall of 20ft, a length on the water line of 16ft 11in, a beam of 6ft 9in, and a draught of 1ft 11in, without fishing equipment, while for propulsion a Parsons " Prawn " 10 h.p. Ford petrol engine conversion with a reverse and two to one reduction gear was fitted. The material selected was an aluminium magnesium alloy to standard specification NS4 for sheet and NE4 for extrusions, while the filler wire for welding was of a composition similar to N5/6 and having a magnesium content higher than the metal to be welded. The boat, which is of twin skeg hard chine design, was jig built and all-welded, using " Argonarc " and " Sigma " processes, as dictated by the thickness of the metal to be joined. The jig allowed the work to be turned through 360 deg. so that the welding operations were greatly facilitated.

Certain items of construction, such as the skegs, keel to stem tube, after knee to stern tube, stem to keel, and transom to after knee, were prefabricated before being erected as a unit with the main construction jig. The unit was held by wooden wedges and then the port and starboard bottom shell plates were faired and tacked into position, followed by the side shell plating. Meanwhile, a number of interior units, including the aft deck and mast brackets to aft bulkhead, the forward bulkhead and 'thwarts, had been assembled and were ready to be placed in position and welded. With the internal structural items of the boat in place the jig was turned through 180 deg. and the final welds were made to the shell plating. Finally, the twin skegs were attached to the hull, which is shown completed in our illustration. The main scantlings are : keel, $\frac{5}{16}$in.; skegs, bottom shell and transom, $\frac{1}{4}$in ; side shell, $\frac{3}{16}$in ; bulkheads, decks and 'thwarts, $\frac{1}{8}$in.

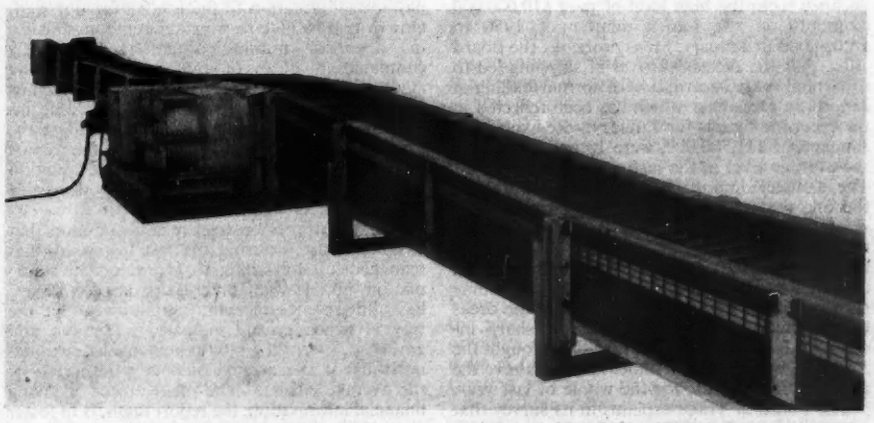
The Parsons Engineering Company, Ltd., supplied the propulsion unit, which is a 1172 c.c. four-stroke petrol engine having four cylinders of 2$\frac{1}{4}$in bore by 3·64in stroke, developing 10 h.p. at 1500 r.p.m., and 24 h.p. at 3000 r.p.m., and driving an alloy propeller. The engine is mounted within a watertight casing, having portable top and semi-portable side plates, fitted with an intake ventilator and an exhaust trunk. Fresh water cooling is provided, the double bottom in the forward well being used as an engine cooling water tank and heat exchanger. This arrangement allows the engine to be started before the boat is launched, so that power is immediately available to help the boat through the surf. There is a 7-gallon capacity fuel tank which is slung under the forward deck in the forepeak, and the stern gear is fitted with a sand excluder, while the rudder is hinged. Particular attention has been paid to the danger of swamping, and to minimise this the fore and aft peak compartments have been made watertight. There are two fish wells, one on each side of the engine casing and bounded by the 'thwarts which, being watertight, as are also the casing side plates, allow both wells to be flooded and so help to keep the catch fresh. Oak towing posts are fitted to port and starboard, and aft there is a portable mast, of Oregon pine, which carries a steadying sail having an area of 26 square feet.

## Articulated-Steel-Plate Conveyor

AN articulated-steel-plate conveyor, known as the " Crocodile," now being made by Richard Sutcliffe, Ltd., Horbury, Wakefield, is illustrated on this page. In this conveyor a belt is formed by steel plate trays 8in by $5^{9}/_{32}$in, bent to form overlapping pans to provide a continuous run. Three standard conveyor sizes are made with widths of 640mm, 800mm and 1000mm, and the carrying capacities vary from 250 to 750 tons an hour. The drive units available can be fitted to the head or tail end of a conveyor or intermediate drives, such as that shown in our illustration, can be fitted at any convenient point.

The supporting structure of the conveyor is built up of rolled steel angles which form the upper and lower tracks for the support rollers of the belt. This framework is supported on steel trestles spaced at 10ft intervals. Brackets riveted to the trays at every 6ft 3in along the conveyor are fitted with a stub axle on which the support rollers are mounted. These rollers are of cast iron and are fitted with two ball bearings with oil and dust seals. Bolted along the sides of the line of trays are double-strand, flat-link chains through which the drive is transmitted.

The drive of the main conveyor motor is transmitted through reduction gearing which gives a chain speed of 160ft per minute with a 1500 r.p.m. prime mover. A series of wire brushes is fitted below the head end of a conveyor to clean the trays. When an intermediate drive is provided power is transmitted through intermediate chains on two pairs of sprockets mounted between the side frames of the conveyor. These intermediate chains are fitted with driving bars with teeth which engage the top flight of the main conveyor chains. By using a number of these intermediate driving units a very long conveyor can be built up and extensions to an existing system easily made.



Articulated-steel-plate conveyor with an intermediate drive

# Industrial and Labour Notes

### Economic Problems and Policies

The Federation of British Industries has published this week a report entitled *Britain's Economic Problems and Policies*. It has been prepared as a result of a survey of current economic affairs which the Federation has recently completed.

The report says that recent events in the Middle East have once more demonstrated how vulnerable is the nation's economy to sudden changes overseas. Despite the fact that exports are nearly twice their pre-war annual volume, Britain is still very far from earning enough abroad to safeguard prosperity at home, to meet her obligations as banker to the sterling area, and to take up again her proper role as a leading investor overseas. If Britain is to secure and keep a larger share of the world's trade, the responsibility, the report suggests, will fall on the energy, resource and competitive ability of industry. It is not enough, the F.B.I. asserts, to contain inflation ; the strength of the economy must be redeployed in such a way as to achieve the highest rate of productive expansion it can contain. But, it is emphasised, nothing less than a fundamental change in policy will achieve this end. There must be a radical reduction in Government and local authority expenditure in order to pave the way for reductions in taxation designed to encourage enterprise, efficiency and thrift, and also to make room for the necessary expansion in investment and exports.

In a section of the report entitled " Remedies," there is emphasis on the fact that technical developments will enable Britain to raise output sufficiently to achieve ambitious plans of social and economic development without risking inflation. Increasing output, the report observes, requires improved material equipment and better human application, but it will remain necessary to adjust the supply of money to the advance in output. The report goes on to say that we need a changing economy, adaptable, resilient, opportunist and enterprising. Full employment, therefore, must leave room for moving from one job to another in accordance with changing techniques and demand. A full employment policy, it is added, must be operated with due regard to other important aims of policy, with which, if pressed too hard, it is not always in harmony. If it produces overfull employment it is dangerous, for overfull employment itself, the F.B.I. comments, bears the seeds of mass unemployment.

### Overseas Trade

The Board of Trade's survey of Britain's overseas trade in January stresses the effect of the blocking of the Suez Canal. The final figure for exports of United Kingdom goods in January was £261,000,000, which was 7 per cent below the monthly average for the final quarter of last year. The Board of Trade says that one-third of this fall is accounted for by the always sharply fluctuating item of ships and boats which declined from the high level of over £10,000,000 a month in the fourth quarter of 1956 to £4,000,000 in January. It is probable, the Board adds, that the delayed arrival of shipping led to some temporary interruption of normal loading of exports in December which has been reflected in the recorded figures for January. Re-exports in January, at £11,700,000, were 10 per cent below the average level in the last quarter of last year. The January import figure of £376,500,000 is the one that reflects plainly the disturbance of normal shipping movements. The delayed arrival of diverted ships reduced imports in the latter half of November and the early part of December, and the Board of Trade's comment is that " some subsequent bunching of arrivals from the areas beyond Suez has contributed to the sharp increase in January." This, it is stated, brought the January import value to almost a sixth above the average monthly rate for the whole of last year.

The Board of Trade explains in its survey that approximately four-fifths of the United Kingdom's overseas trade which normally passes through the Suez Canal is with countries forming part of the sterling area. Total exports (including re-exports) to the sterling area in January, at a value of £118,000,000, showed a reduction of 7 per cent, compared with the fourth quarter of 1956, as did exports as a whole. Analysing the commodity pattern of trade, the Board says that exports of engineering products in January, valued at £99,000,000, were £7,500,000 below the October-December 1956 monthly average, though £6,000,000 of that reduction was accounted for by the sharp fall in January in the exports of ships and boats. Exports in most of the other engineering divisions were well maintained, and, in fact, increased slightly in the case of "machinery other than electric " and railway vehicles. Exports of aircraft, at £5,000,000, were unchanged, and exports of road vehicles and parts (valued at £23,000,000) were £700,000 below the monthly average for the fourth quarter of last year.

### Dollar Exports

In the overseas trade survey, summarised in the preceding note, the Board of Trade says that Britain's exports to the dollar area in January were valued at about £42,000,000, which was 14 per cent below the monthly average in the last quarter of 1956. Exports to the U.S.A. (excluding a further instalment of £2,100,000 of silver bullion repayments) were valued at £21,000,000, but the customary seasonal fall in shipments to Canada brought the January figure for that country to £12,500,000. To both countries, however, exports in January were more than 20 per cent higher than a year ago.

### Financial Information for Employees

The British Institute of Management has just published a report entitled *Presenting Financial Information to Employees*. Its contents are based on the results of a survey among 160 companies. This survey included an examination of the methods being used for the disclosure of financial information ; an assessment of the effectiveness and value of these methods, and the clarification of opinion among managements and employees as to the purpose of giving this information.

The report claims that the number of companies in this country which give financial information to employees is probably less than 20 per cent, although, it is stated " the indications are that this percentage is increasing." Apart from the circulation of their annual reports and accounts, a large number of companies publish information on the general trading position, a matter which is often a regular item on works council agendas. A few companies, the report says, feel that the main purpose of giving information is to make employees cost conscious, and in consequence they publish information on such topics as scrap, the cost of installing new machinery and similar items. But, the report adds, very few companies pay special attention to the needs of senior staff. One or two include sessions on company finance in supervisor training programmes. A few companies, by means of regular meetings, usually at departmental level, believe in keeping senior foremen and departmental managers well informed on all aspects of costs which affect the department. In general, however, the report comments, " it has been noted that little attention is paid to the enlightenment of any levels of management in financial matters."

The report goes on to record an opinion that has been voiced during the last few years that management, by failing to give adequate information about company affairs to employees, has allowed misconceptions to grow about the way in which private industry is financed and governed, until they now dominate the attitudes not only of the average factory worker but of the average citizen. The main object of giving financial information, the report urges, is to foster an understanding, on the part of the employee, of the company's affairs which will help him to identify his own interests with his company's continuing success and stimulate him to make his own contribution towards that goal. Most managements which already give financial information to employees consider that the effort is worthwhile. One observation in the report is that in the companies where individual case studies were undertaken, the majority of employees appeared interested in the information and general morale was very high.

The report (price 21s.) may be obtained from the British Institute of Management, 8, Hill Street, London, W.1.

### Electronic Valves and Cathode-Ray Tubes

The supply of electronic valves and cathode-ray tubes was the subject of a report by the Monopolies and Restrictive Practices Commission, published recently by H.M. Stationery Office. After the passing of the Restrictive Trade Practices Act, 1956, the terms of reference were varied, on August 30, 1956, to require the commission to submit a factual report only. Accordingly, the report contains a description of the industry and its arrangements, but the commission expresses no opinion about the influence of these arrangements upon the public interest.

The Commission finds that the conditions to which the Monopolies and Restrictive Practices (Inquiry and Control) Act, 1948, applies, prevail, in that members of the British Radio Valve Manufacturers' Association (B.V.A.) accounted, in 1954, for 93·5 per cent of the total United Kingdom supply of electronic valves and 92 per cent of the supply of cathode-ray tubes, and that the members have so conducted their affairs as to restrict competition. Furthermore, Mullard Ltd., and its associated companies, were responsible, in 1954, for 67 per cent of the valves and 51 per cent of the cathode-ray tubes supplied in the United Kingdom. The Commission states that, at the time the report was drafted, B.V.A. members restricted competition in the following ways, among others :—common retail prices ; collective retail price maintenance ; agreed discriminatory prices and discounts, including prices for maintenance valves and tubes that were higher than those charged for valves and tubes used for first equipment ; exclusive dealing with equipment manufacturers, wholesalers and others ; discriminatory lists ; restrictions on freedom to import ; and common forms and periods of guarantee. However, the report records that the B.V.A. informed the commission on July 31, 1956, of certain important amendments to the B.V.A. constitution. These changes which were to come into force on September 1, 1956, eliminated price fixing by agreement and collective resale price maintenance.

### The Briggs Dispute

The Minister of Labour has now appointed a Court of Inquiry to examine the dispute at the Dagenham works of Briggs Motor Bodies, Ltd., a subsidiary of the Ford Motor Company, Ltd. A few weeks ago, the company dismissed a shop steward for a breach of discipline, and despite union pressure and campaigning has stated that it is not able to reinstate him. After a ballot among members employed at the Briggs works, the executive of the Amalgamated Engineering Union gave notice of a strike, timed to start last Wednesday. At the end of last week, representatives of the A.E.U. and other unions with membership at the Briggs plant discussed the situation with Ministry of Labour officials, and there were also talks with representatives of the Ford management. The situation did not change materially until Tuesday afternoon when, following the Minister's announcement about a Court of Inquiry, the strike was called off. The company has agreed to pay the dismissed shop steward the equivalent of his weekly wages, pending the report of the inquiry. There is only one member of the Court, Lord Cameron, who will conduct the investigation with the assistance of assessors.

# Solid Wheel and Disc Mill

IN order to cope with the increased demand during recent years for solid wheels for railway rolling stock, Schloemann Aktiengesellschaft, Steinstrasse 13, Düsseldorf, German Federal Republic, has developed a combined forging and rolling process which permits the production of solid wheels from cylindrical billets. Besides railway wheels, turbine discs and similar circular shapes can be produced. Our first illustration shows such a plant, equipped with a 5000-ton forging press, and capable of producing wheels ranging in diameters from 24in to 47in; a 6000-ton plant is at present under construction.

The process has three main stages, namely forging, rolling and dishing-piercing. First, the heated and descaled billet is forged to a rough disc shape between the dies of the hydraulic press, seen on the right in Fig. 2. This press is provided with an intensifier in order to allow working in two pressure stages. (Without the subsequent rolling stage, the press would, it is stated, have to be of much larger size, and two or three pressure stages would be required so as to permit a more intensive initial shaping of the blank.)

A longitudinal shifting device on the base and a transverse shifting device under the moving crosshead make it possible to use two sets of dies. Normally, the blanks for the rolling mill are forged in one stroke, so that the use of two sets of dies serves to more than double the die life. If two different sets have to be used because of a special grade of steel, die changing between strokes can be effected simply and quickly. The moving crosshead contains hydraulic tongs for the transfer of the blank from the first to the second lower die and for centring; a hydraulic ejector is fitted to the base of the machine.

Fig. 1—Wheel and disc mill in operation. The back-up roll is in the foreground

After rough forging, the blank is transferred by means of an overhead hoist to the rolling mill. Details of this machine, which is seen in the centre of Fig. 2, may be gathered from Figs. 1 and 3. An important part of the mill is the special system of guide rolls, consisting of two guide rolls and a back-up roll, which give the wheel a three-point support and keep it vertical during rolling. In this way, an unpunched blank without mandrel can be used, which considerably simplifies the procedure.

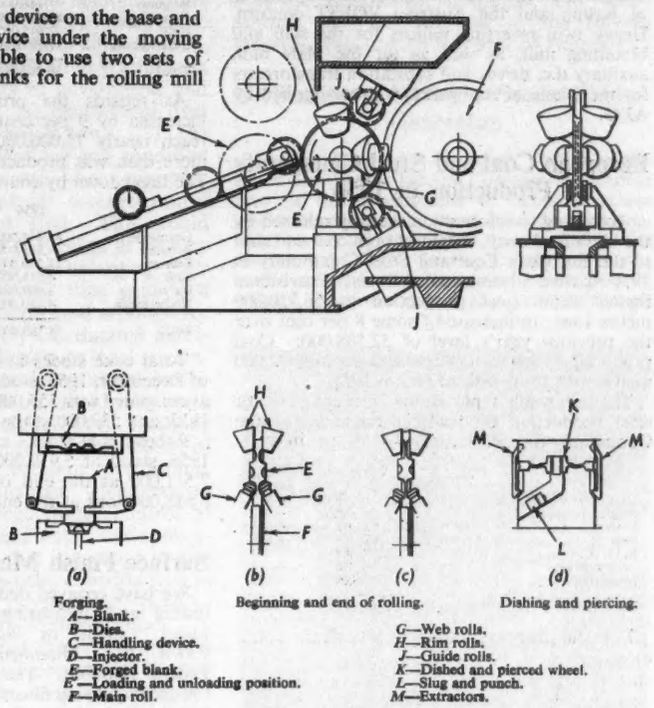



Fig. 3—Wheel and disc mill (top) and principal stages of manufacture

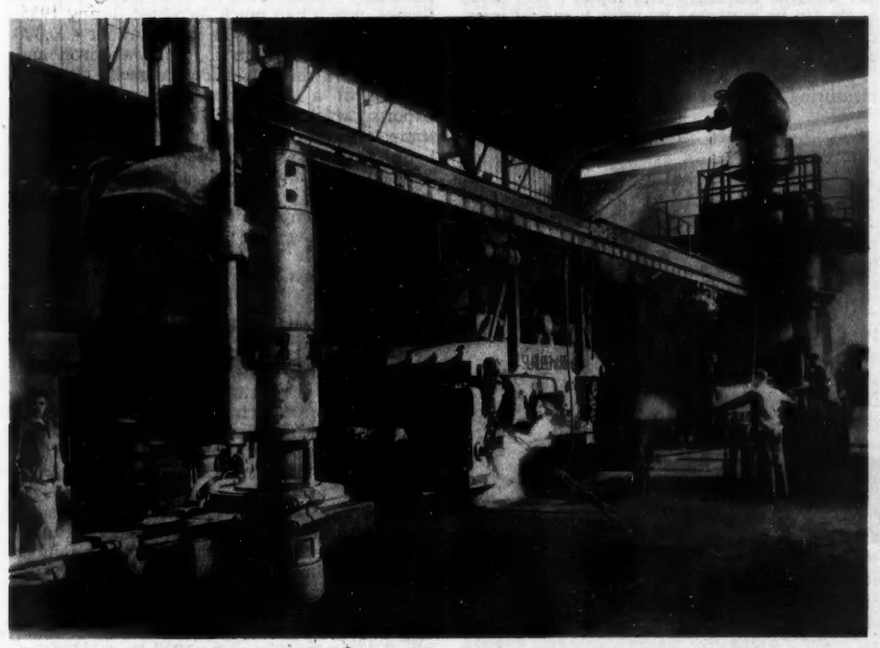


Fig. 2—Wheel forging and rolling plant, showing 5000-ton forging press (right), solid wheel rolling mill (centre), and 1500-ton dishing and piercing press (left). Workpieces are handled by a two-block hoist

The mill scale formed can drop freely, and, as a consequence, it is stated, the required machining allowance is slight. The work is effected by the two conical web rolls and the main roll, all of which are driven by variable-speed d.c. motors; the fact that the main roll is also driven materially increases its action. Two free-running rim rolls shape the rim. They are adjusted by means of an a.c. motor, whereas the web rolls and the main roll are adjusted hydraulically.

Following the rolling operation, the wheel centres are punched and the webs dished in a 1500-ton hydraulic press (Fig. 2, left). Two hydraulically operated hooks fitted to the moving platen serve to lift the completed wheel out of the bottom die, and a hydraulically actuated slide allows both the die and wheel to be removed from the press.

The installation includes an automatically controlled accumulator, the pumps being switched from idling to delivery or vice versa, according to the water level in the bottle.

## Rourkela Steel Works

Last autumn, the Government of India and the German industrial group Krupp-DEMAG signed the final agreement regarding the new steel works and rolling mill at Rourkela (Orissa). This brought to a conclusion negotiations which had been in progress since 1953. The agreement, which is for ten years with the possibility of extension, provides for the foundation of "Hindustan Steel, Limited," with a capital of 1000 million rupees, which will build and operate the works. The majority of the shares is to remain in the hands of the Indian Government; Krupp and DEMAG are to supply capital, equip the plant, send experts, and train Indian technologists in Germany. The steel works is to be built in two stages, each taking four years, and creating an annual capacity of 500,000 and later 1,000,000 tons of steel. Deposits of ore, coal and minerals in Madhyapradesh are being developed.

Further information concerning the plant has

now become available. The principal item of rolling plant is a broad strip mill, which will be built by DEMAG A.G., Duisburg. This firm will also supply a hot-dip tin-plating plant. Other items include a slab and blooming mill, a plate mill, and a cold rolling mill, which are to be supplied by the firms Krupp, Sack, Schloemann, and SIEMAG. The blast-furnaces will be constructed by Gutehoffnungshütte, Oberhausen, and the coking plant by Dr. C. Otto, Bochum. The steel works is to be the joint undertaking of Krupp and the Austrian VOEST concern. Heavy twin reversing motors for the slab and blooming mill, as well as for the plate mill, auxiliary d.c. drives and substation transformers for the whole of the works, will be supplied by AEG.

## European Coal and Steel Community Production in 1956

According to information recently released by the High Authority, output of both coal and steel in the European Coal and Steel Community in 1956 reached all-time record levels. Provisional figures show steel production at 56,720,000 metric tons, an increase of some 8 per cent over the previous year's level of 52,588,000. Coal production rose by 1·1 per cent to 248,992,000 metric tons from 246,401,000 in 1955.

The following table shows a breakdown of steel production by member countries of the Community (in metric tons) :—

| | 1956 | 1955 | Change, per cent |
|---|---|---|---|
| Germany | 23,187,000 | 21,336,000 | +8·7 |
| Belgium | 6,364,000 | 5,894,000 | +8·0 |
| France | 13,390,000 | 12,592,000 | +6·3 |
| Saar | 3,375,000 | 3,166,000 | +6·6 |
| Italy | 5,900,000 | 5,395,000 | +9·4 |
| Luxembourg | 3,455,000 | 3,226,000 | +7·1 |
| Netherlands | 1,049,000 | 979,000 | +7·2 |
| Total | 56,720,000 | 52,588,000 | +7·9 |

For coal the breakdown is as follows (in metric tons) :—

| | 1956 | 1955 | Change, per cent |
|---|---|---|---|
| Germany | 134,378,000 | 130,728,000 | +2·8 |
| Belgium | 29,546,000 | 29,978,000 | −1·5 |
| France | 55,121,000 | 55,335,000 | −0·4 |
| Saar | 17,078,000 | 17,329,000 | −1·5 |
| Italy | 1,049,000 | 1,136,000 | −8·0 |
| Netherlands | 11,821,000 | 11,895,000 | −0·6 |
| Total | 248,992,000 | 246,401,000 | +1·1 |

Community output of pig iron and ferro-alloys also rose to a new record level, reaching 43,569,000 tons, or 6·2 per cent more than the 41,015,000 tons produced in 1955.

| | 1956 | 1955 | Change, per cent |
|---|---|---|---|
| Germany | 17,576,000 | 16,482,000 | + 6·6 |
| Belgium | 5,662,000 | 5,320,000 | + 6·4 |
| France | 11,436,000 | 10,941,000 | + 4·5 |
| Saar | 3,020,000 | 2,879,000 | + 4·9 |
| Italy | 1,936,000 | 1,677,000 | +15·4 |
| Luxembourg | 3,276,000 | 3,048,000 | + 7·5 |
| Netherlands | 663,000 | 668,000 | − 0·7 |
| Total | 43,569,000 | 41,015,000 | + 6·2 |

Output of iron ore in the European Coal and Steel Community in 1956 reached 80,743,000 metric tons, according to provisional figures released by the Statistics Division of the High Authority. This represented an increase of 6·2 per cent over the 1955 figure of 76,028,000 metric tons. The breakdown by countries for 1956 and 1955 was as follows :—

| | 1956 | 1955 | Change, per cent |
|---|---|---|---|
| Germany | 16,928,000 | 15,682,000 | + 7·9 |
| Belgium | 146,000 | 106,000 | +37·7 |
| France | 53,429,000 | 50,885,000 | + 5·0 |
| Italy | 2,645,000 | 2,151,000 | +23·0 |
| Luxembourg | 7,595,000 | 7,204,000 | + 5·4 |
| Total | 80,743,000 | 76,028,000 | + 6·2 |

As regards the production of coke, this increased by 9 per cent over the 1955 level to reach nearly 75,000,000 metric tons, which is more than was produced in any previous year. The breakdown by countries is given below.

| | 1956 | 1955 | Change, per cent |
|---|---|---|---|
| Germany | 43,434,000 | 40,520,000 | + 8·2 |
| Belgium | 7,269,000 | 6,600,000 | +10·1 |
| France | 12,226,000 | 10,725,000 | +14·1 |
| Saar | 4,215,000 | 3,939,000 | + 7·0 |
| Italy | 3,409,000 | 2,949,000 | +15·6 |
| Netherlands | 4,230,000 | 3,901,000 | + 8·4 |
| Total | 74,783,000 | 68,634,000 | + 9·0 |

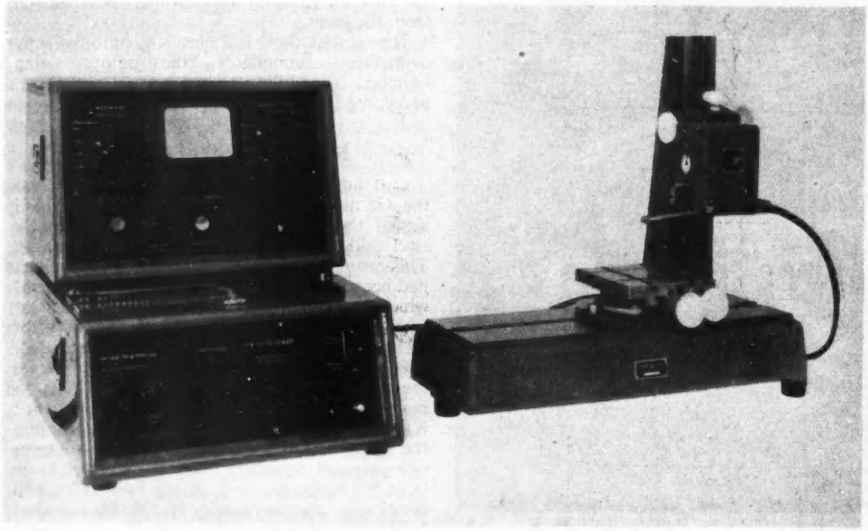
Total coke stocks at coking plant at the end of December, 1956, stood at 531,000 metric tons, as compared with 555,000 at the end of December, 1955, and 539,000 at the end of November, 1956.

Pithead coal stocks at the end of December, 1956, stood at 5,930,000 metric tons, as against 7,511,000 at the end of December, 1955, and 6,618,000 tons at the end of November, 1956.

## Surface Finish Measuring Instrument

We have received details of the surface finish testing and measuring instrument "Perth-o-Meter," made by Hommelwerke G.m.b.H., P.O.B. 30, Mannheim - Käfertal, German Federal Republic. The instrument is shown in the accompanying illustration. It is designed for the absolute measurement, in microns or micro-inches, of all standard surface roughness parameters. These are computed electronically after the stylus has scanned the test piece over a length of $\frac{1}{10}$in (other lengths can be supplied). Each measurement takes a quarter of a minute. Values are obtained for the waviness (machine tool error, peak-to-valley height), roughness (caused by cutting tool), waviness plus roughness, average roughness (RMS, CLA, G), and the bearing area of mating surfaces. A standard tracer is employed for plane surfaces, internal and external diameters, and tapers ; very small bores can be measured by using a special interchangeable tracer. The measuring head may either be used on the machine or on the bench.

The electronic unit (top, left) provides seven measuring ranges (4 to 1000 micro-inches) and five recording ranges (16 to 1000 micro-inches), with vertical magnifications from 1000 : 1 to 100,000 : 1. The recording instrument (bottom, left) is capable of registering frequencies up to 100 c/s. The ratio of vertical to horizontal magnification can be varied between 250 : 1 and 1 : 1 in six steps. A permanent record is obtained without requiring any development. The agent in the United Kingdom is Rubert and Co., Ltd., Chapel Street, Stockport Road, Levenshulme, Manchester, 19.



Surface finish testing and measuring instrument

### Oil Storage in Sweden

According to Press reports, proposals are being prepared for approval by the Swedish Parliament for a gradual doubling of the present reserves of oil products. Present regulations dating from before the war provide for a storage by the oil companies of 15 per cent of the annual turnover in the case of petrol and of 25 per cent in the case of fuel oil. The object of the new proposals is said to be to render the amounts to be stored independent of the annual turnover, and moreover to bring about a dispersal of the quantities stored by extending the obligation to stock reserves to consumers of over 5000 cubic metres per annum. Including power stations, this, it is stated, will involve about 125 undertakings.

The programme of cistern construction and additional imports will require an investment of S.Kr. 600 million, which is to be spread over five years. The total sum includes about S.Kr. 500 million for the distribution sector, of which some S.Kr. 125 million have already been taken into account in previous budgets, so that only S.Kr. 375 million are directly due to the new development. The remaining S.Kr. 100 million approximately are to be spent on expanding the industrial storage capacity (of the 125 concerns which have been mentioned).

### Consumption of Ferrous Scrap in West Germany

According to the German Federal Statistical Office, the total consumption of scrap in the West German iron and steel industry rose during 1956 by 836,000 tons to a figure of 10,957,000 tons. Of this quantity, 5,640,000 tons were obtained from the works' own scrap and 4,660,000 tons came from other German or foreign sources. Expressed as percentages, the consumption of works scrap increased from 48 to 52 per cent, as compared with 1955, while other inland sources accounted for 42 per cent, as compared with 46 per cent in 1955, the remainder—some 641,000 tons—being imports. Stocks, which had much increased during 1955, were reduced by 340,000 tons. About 400,000 tons less of scrap were bought by the iron and steel makers through trade channels, although because of a simultaneous increase in scrap exports, which reached 770,000 tons, the total scrap turnover remained about the same.

Stocks at works at the end of the year stood at 857,000 tons, a decrease during December of 62,000 tons.

Scrap consumption for crude iron showed a reduction during the year to 54 kg per ton, the figure for crude steel being 673 kg per ton, or 5 kg per ton less than in the preceding year.

### Congress on Lightweight Construction

The Verein Deutscher Ingenieure (VDI) announces that a Congress on Lightweight Construction is to be held at the Technical University, Brunswick, on March 21 and 22. The main sections into which the congress will be divided are "full utilisation of materials through correct design for strength," "choice of materials and good production designs in lightweight construction," and "completed lightweight designs in various fields." Many leading scientists and practical engineers from a number of the most important fields of application will speak of their experiences and discuss examples of calculations and design work. Further details regarding programme, and also accommodation, may be obtained from the VDI Design Section (ADK I), Düsseldorf, Prinz-Georg-Strasse 77/79, German Federal Republic.

# The American Scene

BY OUR AMERICAN EDITOR

## Drought in the Great Plains

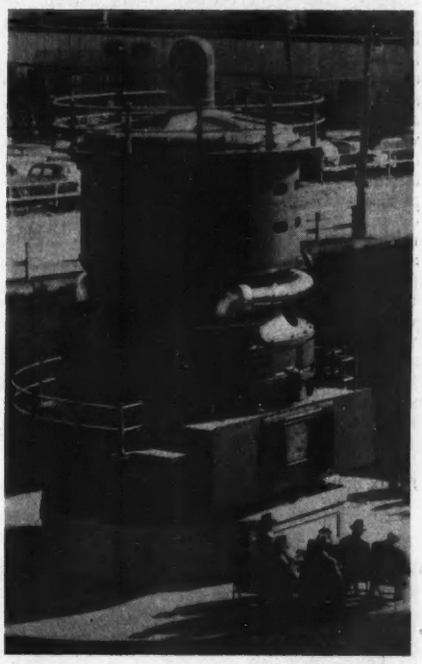
The 1956–57 winter season has been a disastrous one for many farmers and ranchers in the south-western United States. The past November and December were the driest in a hundred years in the Central Valley of California. The December stream flow and storage in New Mexico was the second lowest on record, and the resulting soil moisture and range-land conditions were desperate. On the Salt River project in Arizona, storage was only 10 per cent of the reservoir capacity. The Rio Grande and Arkansas Valleys in Colorado again were deep in drought. In the Washita River Basin scheme of the U.S. Bureau of Reclamation in Oklahoma, the 1956 flow was 180,000 acre-feet compared to a twenty-nine-year average of 1,100,000 acre-feet. In the Central Valley of California, the December precipitation compared with the averages were as follows : 0·20in and 9·33in at the Shasta dam ; 0·42in and 4·06in at the Folsom dam, and 0·72in and 2·15in at the Friant dam. Yet, despite these staggering figures, little was said publicly about compulsory conservation measures during President Eisenhower's recent two-day tour of the drought areas. Behind the scenes, however, the recent drought and its economic consequences have generated a revival of ideas to gain an enforcement of measures for putting land to its best use. The despoliation of forests by timber barons of an earlier day and the depletion of some mineral and other natural resources have brought the conservation of national resources forward with rapid strides. But on a national scale little is being done to turn man from a miner of the soil into a steward of the land. Both office holders and seekers have followed the line that it is better to provide relief in times of disaster and hope for the best through voluntary conservation programmes than to enforce land-use regulations.

On the national level, Congress has consistently adhered to the voluntary approach on conservation. The Eisenhower administration, like its predecessors, has been reluctant to increase Federal controls on agriculture except as the farmers themselves vote regulatory programmes as price-support aids. Only recently the president of one of the country's largest farm organisations said that he could not favour any Federal or state land-use restrictions except through some method such as zoning. He gave as an example the zoning of land to prevent the ugly strip-mining of coal. It is doubtful that Congress will take up this year the fundamental problem of the relationship of Federal, state, local and private interests to gain the land-use changes needed to combat drought and other disasters. Yet many members of Congress and high officials of the Administration concede that the recent drought and its land problems have raised questions of national scope. However, they believe that their province is to encourage states to attack the problem through county and local governments. All agree that a great deal of the needed land-use adjustment to prevent the continued ploughing of land unsuited to cultivation and the over-grazing of land easily damaged by wind or other erosion can be attained within the framework of existing regulations. There remain, however, large problem areas, such as the drought districts of to-day, where only a firm national and state policy appears to be the solution to the land problem. There are many avenues open. All have been advanced from time to time. All require concerted action from Washington down to the local units of government and individual land users. As enumerated over the years, the major points are : (1) The requirement of sound land use as a condition of eligibility for Federal price supports. (2) The adjustment of all acreage-control programmes to fit the land. This would mean the prevention of ploughing of land by producers for the sake of enlarging their historical base-acreage and thus gaining a larger acreage allotment on land unsuited for continued cropping. (3) Contractual agreements between Federal, state or local governments and producers to bring about individual farm adjustments in conformity with sound land-use principles. (4) Enabling legislation by states to meet the problems of land-use when needed, including rural zoning, district land-use ordinances, wind erosion regulations, grazing regulations, control of surface and underground water and application of tax procedures that encourage proper land use. (5) State financial contributions in all Federal farm-aid programmes, particularly those dealing with conservation.

The closest the United States has come to a sizeable effort on enforcement of known measures for soil conservation is the creation of Soil Conservation Districts. All forty-eight states now have laws authorising Soil Conservation Districts to be established voluntarily by farmers. The districts are joined together in a national association that undertakes to promote the district principle. The district plan facilitates soil saving in two ways : through educational programmes that show the way to farmers and by providing a mechanism through which producers can work together to solve community-wide problems. In some states they may, by a majority or a two-thirds vote, ban certain undesirable farming or grazing practices. In some states the districts also have the power to raise funds through assessments on land that benefits. The districts grew from a model advanced by the Federal Soil Conservation Service that led the fight against the " dust bowl " of two decades ago. The " dust bowl " also produced in some states land-use laws governing the cropping of land. But when corrective measures were taken in the " dust bowl " days, quarrels developed with property owners, and officials shied away from bearing down on non-co-operators. Fortunately, the social problem of to-day is not as great as it was when the " Okies " fled the seared land twenty years ago. In some areas, however, individuals and families will require aid for resettlement and perhaps for retraining to take jobs in industrial or other fields. At the moment, the Administration is increasing relief in the form of added credit through loans and cut-rate feed and hay. It is pushing its " Great Plains " programme aimed at gaining ten-year contracts with producers to instal soil-and-water-saving practices with the Government paying 80 per cent of the cost. All these efforts, however, remain voluntary. Whether public opinion will bring about enforceable conservation remains to be seen. In the final analysis, only a fully-co-ordinated region-wide plan taking into account crop controls, land-use limitations, irrigation and water storage, can put an end to the forever recurring disasters in this part of America.

## Dedication of Historic Steam-Turbo-Generator

A " MONUMENT TO COURAGE," which established The General Electric Company as a leading firm in the development of electrical power generating equipment, was dedicated at Schenectady, New York, recently as " an inspiration for the future." The " monument," which is shown in the accompanying illustration, is the 5000kW vertical steam-turbo-generator unit which was



**5000kW General Electric vertical steam-turbo-generator during dedication ceremonies at the Schenectady works**

put into service at the Fisk station of the Commonwealth Edison Company in Chicago, in 1903. At the time of installation, the unit was the world's most powerful electric generating machine. The construction of this steam turbo-generator unit represented a radical departure from the reciprocating steam engine and established The General Electric Company as one of the leaders in the design and production of powerful and efficient steam turbines employed for generating purposes.

## Construction of 100,000-ton Tanker

A CONTRACT for the construction of a 100,000-ton petroleum tanker, which will be the world's largest vessel, was signed in New York in December by representatives of Victory Carriers, Incorporated, and the Shipbuilding Division of the Bethlehem Steel Company. Its fully loaded displacement tonnage of about 130,000 tons will exceed that of any vessel now in operation or under construction. The tanker will be built in the United States and operated under the American flag. The contract, which calls for the construction of two 46,000-ton tankers, in addition to the 100,000-ton super-tanker, at a total cost approximating 55,000,000 dollars, was signed by

Captain Granville Conway, president of Victory Carriers, who announced that the super-tanker would have an overall length of 940ft and a beam of 132ft. It is expected to operate in the Persian Gulf–U.S.A. trade, and, when fully loaded, will have to go around the Cape of Good Hope, but will be able to pass through the Suez Canal when empty. The liquid capacity of the 100,000-ton tanker will be in the neighbourhood of 825,000 barrels. The tanker will have a cruising radius of 26,000 miles and her two engines, powering twin screws, will give her a speed of more than 17 knots. This speed will make the tankers valuable assets to the United States Merchant Navy in the event of a national emergency. Also, the tanker will be able to carry more than fifty aircraft on deck as compared with the eighteen aircraft carried by "T-2" tankers during World War II.

The two 46,000-ton tankers included in the construction contract between Victory Carriers and Bethlehem also are expected to operate in the Persian Gulf–U.S.A. trade and will operate under the American flag. All three vessels will be built at the Quincy yard of the Bethlehem Steel Company in Massachusetts.

# Continuous Casting Machine for Non-Ferrous Metals

THE development of an automatic continuous casting machine to handle both heavy and light non-ferrous metals has been announced by Lobeck Casting Processes, Incorporated, of New York. Compared with conventional casting facilities, this machine is said to offer vastly improved productivity, coupled with the highest quality of ingot obtainable. The casting machines are extremely compact, simple to operate and require only a very modest investment which is within reach of even the small foundry. Fewer casting shop operators, instantaneous mould change-over, negligible maintenance cost and absence of mould lubricating labour are some of the advantages which are being claimed for the machine. The equipment (examples of which are illustrated here) is already operating successfully in various non-ferrous metal works in the United States, casting a wide variety of shapes varying from round extrusion billets—solid as well as hollow—to rectangular rolling mill cakes and slabs. The machines are capable of producing billet sizes from 3in to 20in diameter, and simultaneous casting of as many as twenty multiple strands is now being done. Less than 1 per cent of the metal is lost in the form of "gate" on top of the ingot, which is a great improvement compared to the scrap loss which is involved in conventionally cast ingots.

The Lobeck casting units can be arranged for either continuous or semi-continuous operation depending upon the application involved. Since the semi-continuous machines can produce multiple strands up to 25ft length, it is usually not necessary to go to the continuous arrangement with its more elaborate requirements for flying cut-off saw equipment, &c. The machines can handle practically all non-ferrous metals and alloys, including aluminium, electrolytic, tough-pitch and oxygen-free copper, plain and leaded brasses, bronzes, cupro-nickel, nickel silver, nickel, zinc and precious metals and alloys. Due to a special automatic flow-control system employed, it is possible for a single machine operator to be responsible for the casting of multiple strands of these metals. The mould equipment is manufactured with great care and precision, resulting in castings of the highest obtainable density, accuracy and overall tolerance. Carefully controlled lubrication of the mould casting interfaces ensures a cast surface free of defects, so that conditioning and scalping is generally not required. From a quality point of view, the continuously cast ingots are greatly superior to those cast by conventional methods, particularly since the grain size of the cast material can be controlled to suit the ultimate application by regulating the speed of casting and the hot metal temperature.

The Lobeck casting machine consists of the following basic components :—(1) Oil-hydraulic cylinder for the lowering and lifting movements of the platform ; (2) welded steel water tank fitted with a swivel ring supporting the various moulds ; (3) cast iron base plate supporting the entire machine ; (4) welded steel casting table, with bore in hub to connect to oil-hydraulic cylinder ; (5) masonry bolts, packings and bolts for the complete assembly of the machine ; (6) oil-hydraulic power unit, including pump, motor, oil reservoir and control valve ; (7) pressure-compensating feed valve with mounting plate ; (8) billet length indicator, and (9) transfer trough for metal flow from the holding furnace to the distribution pan. Furthermore, an initial set of metal moulds mounted in a carrying frame, the mould stools mounted on plates, and the metal distributor, are furnished with the casting machine.

Hot metal for the continuous casting operation is generally obtained from induction or reverberatory melting furnaces feeding an induction or resistance-heated holding furnace. To start the casting operation the swivel ring supporting the moulds is moved to rest centrally on the water tank. The casting table, which supports the mould bottoms, is raised by its oil-hydraulic cylinder until the mould bottoms contact the moulds, thus effecting mould closure. The metal is now allowed to run from the holding furnace through the transfer trough into the distribution pan and from there into the individual moulds. The distribution pan is lined with a special refractory, which eliminates preheating. Molten metal is fed into the moulds under automatic flow control, maintaining a rate equivalent to the rate at which the solidifying castings move downward. The short length of the mould and its high thermal conductivity facilitate rapid solidification of the metal. The moulds are made of a special alloy and are internally cooled by water circulation. The cooling water can be recirculated, so that only a small amount of make-up water is required. Upon leaving the moulds, the ingots are further cooled by controlled water sprays and, finally, are immersed in the water contained in the welded steel tank. The water level in the tank

Continuous casting machines for simultaneously producing (left) eight 6in diameter aluminium alloy extrusion billets, (right) three 8in diameter brass ingots

is controlled by overflow provision. On the completion of the pour, the mould supporting ring is swivelled aside about its pivot support, thus permitting an easy access to the solidified ingots resting in the tank. An overhead crane is used to lift the castings out of the tank.

## Twenty-High Cluster Mill for Rolling Ultra-Thin Strip

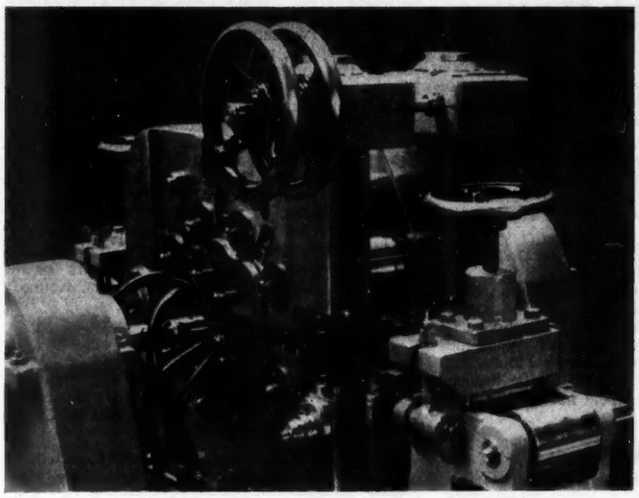
AN interesting twenty-high reversing Rohn cluster rolling mill, introduced by the Loma Machine Manufacturing Company, of New York, has been developed for the reduction of narrow-width strip from about 0·010in to 0·0001in. Already established in the processing of such highly work-hardening metals as 18–8 stainless steel, high-temperature "super alloys," silicon steel, tantalum, molybdenum, beryllium copper, platinum alloys, nickel-iron alloys and similar magnetic materials, the machine is filling the current need in the United States for a narrow-width cluster rolling mill for the production of ultra-thin strip. Its relatively low cost and simple design also bring this equipment within reach of metallurgical laboratories and pilot plants who had been unable in the past to afford the expense of more elaborate cluster mills.

The new machine, which is shown in the accompanying illustration, is available in a number of sizes, employing such work rolls as $\frac{1}{16}$in by 4in, $\frac{1}{4}$in by 4in and $^{9}/_{32}$in by 3in. Furthermore, the mill drive can be applied either to the work rolls, the intermediate rolls or the back-up rolls. The mill is also available in a twelve-high design, and a six-stand tandem arrangement of this type with 1$\frac{1}{4}$in by 7in work rolls is being used in the cold reduction of carbon steel strip to 0·004in. The machine is normally powered by a variable-voltage d.c. drive, arranged for constant tension winding. Generally, a variable-speed range up to 100ft per minute and a coil build-up range from 6in I.D. to 12in O.D. is provided. By using a dual set of coilers, a tension range as high as 1000 : 1 is obtainable.

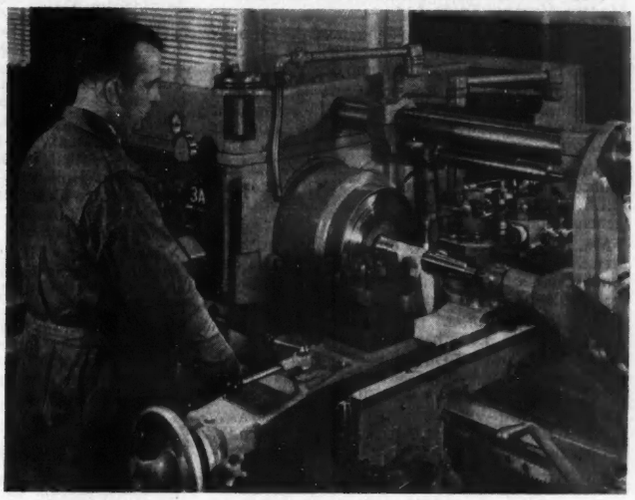
Compared with a conventional four-high unit, this Rohn mill can finish-roll strip to considerably thinner gauges, taking much heavier reductions per pass and greater total reductions between anneals. Moreover, the cluster mill can hold the closest obtainable thickness tolerances and produces strip of excellent flatness, even at 0·0001in finishing thickness. Such ultra-thin gauge cannot be obtained on ordinary mills with relatively large work rolls because the very high ratio of contact length to strip thickness causes an extremely high resistance to deformation. The cluster arrangement has the additional advantage of preventing the bowing out of the slender work rolls in the direction of forward tension, which makes it difficult in the four-high mill to maintain the correct strip shape.

The principal improvement incorporated in the new design is the use of proper back-up rolls with heavy-duty anti-friction roll neck bearings instead of idler back-up bearings mounted on non-rotating shafts. This improvement is claimed to permit 60 per cent higher rolling pressures and facilitates the greatest possible concentricity and, hence, closest strip thickness tolerances. The high-precision dual handwheel worm gear screw-down mechanism allows extremely accurate gauge and camber control and is equipped with a quick-acting opening device used in threading the strip through the mill. In the back-up driven arrangement of the machine, the work rolls, which are made either of alloy steel or tungsten carbide, can be changed within one minute. For purposes of pass control, the mill may be equipped with continuous gauges indicating roll separating force, strip tensions and stock thickness.

At present, there are three reversing Rohn cluster rolling mills in operation in the United States, employed principally in the reduction of magnetic materials. They are in use at the Allegheny Ludlum Steel Corporation, in Pennsylvania, the U.S. Naval Ordnance Laboratory at Silver Spring, Maryland, and the Bell Telephone Laboratories at Summit, New Jersey. A fourth one will shortly be installed for the processing of tantalum foil by a prominent manufacturer of capacitors.



Twenty-high reversing Rohn cluster rolling mill, with driven $\frac{1}{16}$in diameter work rolls



Hydraulic contour tracing attachment mounted on Warner and Swasey No. 3A turret lathe

## Hydraulic Contour Tracing Attachment for Turret Lathes

A HYDRAULIC contour tracing attachment, designed for accurate contour turning and cross-centre contour facing operations with heavy-duty turret lathes, has been developed by the Warner and Swasey Company, of Cleveland, Ohio. This unit complements the turret-mounted internal contouring slide tool introduced by the company for these same machines several months ago. Capable of heavy metal removal in the contour turning and facing of both average and large-size workpieces, the attachment provides precise control of successive roughing, semi-finishing and finishing cuts, using a single flat or round template as the master pattern. The tracing attachment, which is shown in the accompanying illustration, mounts at a 45 deg. angle on the rear of the cross-slide and incorporates a six-position, hydraulically-operated stop-roll similar in design to the stop-roll mechanisms used with the cross-slide and hexagon turret units on the Warner and Swasey lathes. By presetting the individual stop-screws of the tracer stop-roll to the desired depths of cut, as many as six successive template-controlled cutting passes across the workpiece can be made, without need for any manual cutting tool adjustments by the operator. By using the attachment, a substantial reduction in machining time is possible, since successive heavy roughing cuts and lighter finishing operations on contoured parts can be completed swiftly in only one set-up without template changing being required.

The single template pattern for the tracing attachment is mounted in a bracket attached to the overhead pilot bar of the unit. Flat templates are held in a clamp mount, while round templates utilise a pair of simple centre adaptors. Micrometer adjusting screws are employed to facilitate the accurate alignment of the template with the spindle axis. The conversion of the tracer from contour turning to facing operations is accomplished quickly with the installation of a special holder in the template mounting bracket which positions the facing template at an angle of 90 deg. to the spindle centre line. No other changes are necessary. A two-position hydraulically-indexed and clamped turret holds the roughing and finishing cutters. By performing all rough cuts exclusively with the roughing cutter, the finishing cutter is saved for light finishing operations. The actuation of the tracer slide is by means of a large hydraulic cylinder powered by a separate hydraulic pump unit. The cylinder has a 6in stroke and provides an effective maximum cutter travel of 4in, thus permitting the contour turning of workpieces having up to an 8in diameter differential or the contour facing of workpieces with a height difference as great as 4in. The hydraulic system is of the differential pressure design, regulated by a micro-sensitive, stylus-controlled valve. The stylus employs a flexure pivot—thin strips of spring steel—to eliminate any lost motion or play during operation. By retracting the tracer to its rearmost position when not in use, the lathe on which it is mounted may be utilised for standard turret lathe work whenever desired without danger of tool interference.

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WASHINGTON UNIVERSITY RESEARCH COMPUTER LABORATORY.—We learn from *The Trend in Engineering at the University of Washington*, published quarterly by the engineering experiment station of the University, that a separate department called the research computer laboratory has been established there. This laboratory is to be used for about twenty hours a week by students in numerical analysis and data processing, for course work and for class demonstrations. The main equipment in the new laboratory is an "IBM650" magnetic drum data processing machine, which is being rented, together with the associated card handling machines. A key punch, verifier, interpreter, reproducer, sorter and tabulator are also installed. A storage capacity of 20,000 decimal digits is inherent in the computer. Among the applications which are being studied are power flow and volt drop problems in an electrical network with several busbars. The possibilities of language translation, especially Russian to English, are being studied, by using the computer to test routines for the logical processing of material to produce intelligible outputs.

# Personal and Business

## Appointments

DR. HAROLD HEYWOOD, M.I.Mech.E., has been appointed principal of the Woolwich Polytechnic.

THE DUKE OF NORTHUMBERLAND has been elected president of the Institute of General Managers.

TECALEMIT, Ltd., Plymouth, states that Mr. R. F. Brooker has been appointed general sales manager.

TUBE INVESTMENTS, Ltd., has announced that the Rt. Hon. The Lord Clitheroe has been appointed a director.

VICKERS, Ltd., has announced that Mr. E. O. Faulkner and Mr. G. H. Houlden have been appointed directors.

MR. JACK WALLACE has been appointed S.E. London and Southern Counties representative of A. A. Jones and Shipman, Ltd.

MR. P. E. VERRALL has been appointed a director of Precision Machinery Services, Ltd., a subsidiary of Modern Machine Tools, Ltd.

PLENTY AND SON, Ltd., has announced the appointment of Mr. S. G. Brown as a director. He will continue to be responsible for the pump department.

MR. DENIS WRIGHT, technical representative, has been transferred to the industrial sales department of H. Leverton and Co., Ltd., Spalding, from its northern area sales office.

THE CENTRAL ELECTRICITY AUTHORITY has announced the appointment of Mr. G. R. Peterson, M.I.E.E., M.I.Mech.E., as deputy chief engineer (generation and system operation).

MR. R. G. F. GRIFFIN has been appointed manager overseas manufacturing, of F. Perkins, Ltd., and Mr. John Taverner has been appointed chief instructor of the instruction school at Peterborough.

THE INTERNATIONAL HARVESTER COMPANY OF GREAT BRITAIN, Ltd., has announced that Mr. C. Gordon Davis has been appointed manager of manufacturing. He has been succeeded as works manager at Bradford by Mr. Frank J. Zmarzly.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., states that Mr. A. O. Ahlquist, A.M.I.Mech.E., has been appointed assistant sales manager, mechanical department. Mr. N. J. Austin has been appointed assistant to sales manager in the same department.

TILTMAN LANGLEY, Ltd., has announced the following appointments :—Mr. L. A. Wingfield, chairman ; Major H. H. Sykes, managing director ; Mr. Marcus Langley, technical director, and Mr. L. D. Neeves, secretary. Mr. N. W. Collett has been appointed a director.

CAPTAIN H. F. ATKINS has retired from the engineering branch of the Navy after thirty-nine years' service. He has been appointed Secretary to the executive committee of Vickers Nuclear Engineering, Ltd., and assistant to Rear-Admiral Sir Edward Rebbeck.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., has announced the creation of two new posts on the aeronautical engineering staff. Mr. G. P. Parker, A.M.I.E.E., has been appointed deputy chief air radio engineer (development), and Mr. J. H. Gill has been appointed deputy chief air radio engineer (projects). The following appointments as technical representatives on the engineering sales staff have also been announced :—Mr. B. J. Infield (overseas) ; Mr. E. Swinney, M.I.E.E. (home) ; Mr. E. Hird (U.S.)

IMPERIAL CHEMICAL INDUSTRIES, Ltd., has announced the following appointments :—Metals Division : Dr. Maurice Cook has been appointed chairman and his place as joint managing director has been taken by Mr. St.J. Elstub ; Mr. W. H. G. Lake and Mr. W. M. Ismay have been appointed directors. Nobel Division : Dr. J. M. Holm has been appointed joint managing director, and Dr. A. D. Lees, a director, with effect from April 1 ; Dr. W. A. Caldwell has been appointed development director. Paints Division : Dr. J. S. Gourlay has been appointed chairman. Wilton Council: Mr. J. C. H. McEntee has been appointed chairman and his place as managing director has been taken by Mr. R. E. Newell.

## Business Announcements

INCORPORATED PLANT ENGINEERS states that it has changed its address to 12, The Parade, Solihull, Warwickshire (telephone, Solihull 1111).

MR. B. C. MORTON, managing director of Robert Dempster and Sons, Ltd., will leave England on March 28 for a business visit to South Africa.

KEITH BLACKMAN, Ltd., states that the Blackman Export Company, Ltd., 23, Queen Square, London, W.C.1, is now a wholly owned subsidiary of Keith Blackman, Ltd.

INVENTIONS FOR INDUSTRY, Ltd., Palace Chambers, Bridge Street, London, S.W.1, has been set up to assist inventors to place their work and to secure the most advantageous terms.

SQUARE D., Ltd., states that it has opened a new branch office at 235, Bath Street, Glasgow, C.2 (telephone, Central 3260). Mr. Robert Brodie has been appointed area manager.

THE STELLA LAMP COMPANY, Ltd., states that the address of its headquarters and administrative offices has been changed to 158/160, Shaftesbury Avenue, London, W.C.2 (telephone, Covent Garden 3031).

MR. J. E. C. BAILEY, chairman and managing director of Baird and Tatlock (London), Ltd., Hopkin and Williams, Ltd., and W. B. Nicolson (Scientific Instruments), Ltd., is making a short tour of Africa.

STANDARD TELEPHONES AND CABLES, Ltd., states that it will open a cable depot and warehouse at 33, Pilcher Gate, Nottingham, on March 4 (telephone, Nottingham 52333). The depot will be under the management of Mr. R. N. Baylis.

MR. FREDERICK FRANKS, director of Geo. Robson and Co. (Conveyors), Ltd., and the Furnival Steel Company, Ltd., states that he is leaving this country on March 8 on a business trip to South America. He will visit Brazil, Uruguay and the Argentine.

THE CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., states that it has formed a new subsidiary company in Holland. The new company, known as N.V. Chicago Pneumatick, is under the control of the following directors :—Mr. N. Readman, Mr. K. Zeevenhooven and Mr. R. R. Parker.

RANSOME AND MARLES BEARING COMPANY, Ltd., Newark-on-Trent, has issued a *cri-de-cœur* on behalf of a doctor who nearly three years ago took over from the firm premises formerly used as its branch office in Leeds. He still receives up to twenty telephone calls a day intended for the firm ! When the branch office was moved to St. Paul's House, St. Paul's Street, the telephone number of the branch became Leeds 32094/5, not—repeat not—27133.

## Contracts

VICKERS-ARMSTRONGS (TRACTORS), Ltd., states that it has secured an order for heavy construction tractors and equipment from the Government of Pakistan. The value of the order is approximately £900,000.

SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT, Ltd., is to build sixty-eight Hawker "Sea Hawk" Mk. IV fighters for the German Naval Air Arm. Including spares and equipment, the aircraft will cost over £5,000,000.

J. SAMUEL WHITE AND CO., Ltd., has received from the Admiralty, acting on behalf of the New Zealand Government, an order for a "Whitby" class anti-submarine frigate. The company has also received, from the Corporation of Trinity House, a contract for a further lighthouse tender.

INTERNATIONAL HARVESTER COMPANY OF GREAT BRITAIN, Ltd., has received initial orders from Canada, valued at more than 1,500,000 dollars, for 1000 B-250 diesel tractors and direct-connected implements. Production of this tractor was started about a year ago (THE ENGINEER, December 9, 1955).

THE MARCONI INTERNATIONAL MARINE COMMUNICATION COMPANY, Ltd., has received orders, for "Radiolocator IV" radar equipment for thirteen ships of the Shaw Savill Line, for twenty-eight "Oceanspan" transmitters for ships of the Harrison Line, and for twenty-two "Salvare" equipments from the British India Steam Navigation Company, Ltd.

THE CLEVELAND BRIDGE AND ENGINEERING COMPANY, Ltd., has been awarded the main contract for the second stage of the Neath by-pass on the London-Cardiff-Fishguard trunk road, South Wales. The Ministry of Transport says that work on the new section will begin within a few weeks. The first part of the scheme, recently completed, was a bridge and viaduct over the railways and waterways between Briton Ferry and Earlswood. The second part, estimated to cost nearly £1,750,000 (including land), extends the road from Earlswood to Lonlas, a distance of 2½ miles.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., has received an order worth about £150,000 from the National Coal Board for two a.c. electric winder equipments for installation in the East and West Shafts of Nine Mile Point Colliery, near Ystrad Mynach, Glamorganshire (No. 5 Area, S.W. Division). Both will be of a.c. geared equipment, being driven by slipring induction motors connected direct to the 3·3kV supply ; the motors will be arranged for dynamic braking, using a d.c. supply from mercury arc rectifiers. The East Shaft winder will have a 17ft diameter drum driven by a 1850 h.p. motor with a liquid controller designed to allow the provision of closed-loop control at some future date. The West Shaft winder will be an 850 h.p. equipment driving a 16ft diameter drum. The electrical equipment of both winders will be of Metropolitan-Vickers manufacture, the mechanical parts being made by Robey and Co., Ltd., and M. B. Wild and Co., Ltd., acting as sub-contractors.

THE MITCHELL CONSTRUCTION COMPANY has been awarded two contracts, worth £3,750,000 in all, for constructional works in Scotland, for electricity generation. The first contract, which is valued at £2,500,000, is for the construction of over 13 miles of tunnels on the Killin section of the North of Scotland Hydro-Electric Board's Breadalbane scheme in Perthshire. The contract also includes the construction of pipeline aqueduct sections totalling 8 miles, the laying of access roads covering many miles, and the construction of the associated intake weirs and shafts. Two camps will be built and maintained by the company, and the contract will cover three years. The consulting engineers for the project are Messrs. James Williamson and Partners. The second contract, which is worth £1,250,000, was awarded by the South of Scotland Electricity Board for work on the new thermal generating station at Kincardine, Fife. The company will be responsible for the construction of the superstructure of the main building, the turbine house, boiler house, administration and workshop blocks, and other ancillary buildings. Work will begin on the site immediately and the station is due for completion in about three and a half years. The consulting engineers for the Kincardine generating station are Messrs. Kennedy and Donkin.

## Miscellanea

MR. BERT STEVENSON.—We record with regret the death of Mr. Bert Stevenson, which occurred on February 17. He was chief draughtsman of Lancashire Dynamo and Crypto, Ltd.

ELECTRONICS EXHIBITION.—An exhibition will be held in the College of Science and Technology, Manchester, on March 26 and 27, 1957, 10 a.m. to 9 p.m., by the Radio and Telecommunications Group of the North Western Centre of the Institution of Electrical Engineers. It is intended to stimulate recruitment to the electrical engineering profession. Demonstrations of working electronic equipment will be given.

MR. EWEN H. SMITH.—We record with regret the death of Mr. Ewen H. Smith, the chairman and managing director of David Rowan and Co., Ltd., which occurred last week at his home in Bearsden, Glasgow. Mr. Smith, a past chairman of the National Association of Marine Engine Builders, was a vice-president of Scottish Engineering Employers' Association, and of the Institution of Engineers and Shipbuilders in Scotland, and a member of the Clyde Navigation Trust. He served his apprenticeship with Earles Shipbuilding and Engineering Company, Ltd., and after serving in the first world war joined Workman Clark and Co., Ltd., becoming a director in 1932. For a number of years Mr. Smith was associated with the Central Marine Engine Works of William Gray and Co., Ltd., which he left on his appointment as deputy managing director of David Rowan and Co., Ltd., in 1945. In 1948, he became managing director and four years later he was appointed chairman.

AUTOMOBILE REFINEMENT.—Vauxhall Motors, Ltd., has introduced a car—the "Victor"—smaller and lighter than the present "Wyvern." The engine is of the same swept volume, 3⅛in by 3in, but a separate pair of ports for every cylinder and larger (1·437in diameter) inlet valves allow the torque to be maintained to higher revolutions per minute, the net output being 48 h.p. at 4200 r.p.m. (gross 54·8 h.p.), with a compression ratio of 7·8 ; the alternative ratio of 6·8 reduces the gross power to 52 h.p. at 4000 r.p.m. The engine is built ½in *desaxé* to ameliorate piston slap. A downdraught carburettor is used, but the air cleaner is beside it to allow the bonnet to slope down from the windscreen. An all-synchro-mesh, three-speed transmission is used ; direct drive gives a piston travel of 1817ft per mile. The front suspension is mounted on a cross member attached to the body by widely spaced rubber cushions ; this allows the wishbone pivots to be grease-lubricated plain bearings, with a consequent improvement in tyre life. The rear springs are negatively cambered to give a positive static margin despite Hotchkiss drive ; the design is claimed to have a high polar moment of inertia. The kerb weight of the car is 2120 lb or 2150 lb in "Super" form.

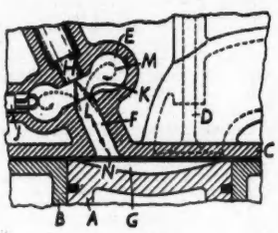
# British Patent Specifications

*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, Price 3s. each.*

## INTERNAL COMBUSTION ENGINES

**766,233.** March 21, 1955. — PRECOMBUSTION CHAMBER DIESEL ENGINES, The Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention relates to precombustion chamber diesel engines having an open through-flow duct extending in the direction of the injection nozzle and connecting the precombustion chamber with the main combustion chamber without obstruction. According to the invention, the fuel is sprayed substantially in the direction of the open through-flow duct, but wholly, or to a substantial extent, at an acute angle against the wall of the duct. Referring to the drawing, a piston *A* is shown at the top of its stroke in a cylinder *B*, which is one of a series. Inlet and exhaust valves are mounted in the cylinder head *C* and one valve is shown at *D*. A precombustion chamber *E* on the opposite side of the longitudinal axis of the cylinder to the valves is of flattened or disc form comprising a shallow central or axial part surrounded by a deeper annular part of circular cross-section. This chamber is connected by way of a relatively long unobstructed through-flow duct *F* to the main combustion chamber *G*, which is formed by a shallow depression in the piston crown. The common axis of the precombustion chamber and through-flow duct extends at an acute angle to the longitudinal axis of the cylinder, the through-flow duct and the injection nozzle *H* being coaxial and the through-flow duct opening out into the main combustion chamber eccentrically of the cylinder. A glow plug *J* is arranged laterally in the cylinder head for heating the precombustion chamber. As can be seen, the through-flow duct, which is of relatively large diameter has a length which is a multiple of the axial depth of the precombustion chamber when measured between the injection nozzle and the mouth of the duct opening into the precombustion chamber. The fuel is sprayed from the nozzle *H* in a hollow conical



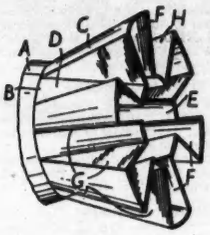

No. 766,233

veil *K* at an acute angle evenly towards the wall of the through-flow duct *F*, where it impinges still in liquid form on the wall after being sprayed for a relatively short distance through the precombustion chamber and covers the duct wall with a thin layer. The air flowing through the open duct in the direction *L* during the compression stroke of the piston then removes the fuel from the wall in a partially vaporous state and distributes it in the annular part of the precombustion chamber by an annular turbulence *M*. As soon as ignition has started in the precombustion chamber, the further fuel still injected towards the wall of the duct *F* after this moment is taken up by the contents of the precombustion chamber and blown into the main combustion chamber in the direction of the arrow *N*. If desired, some of the fuel may be sprayed in a straight line directly through the duct into the main combustion chamber or laterally into the precombustion chamber. Modified designs, in which the duct *F* is slightly conically enlarged towards the precombustion chamber or on a funnel-like surface, slightly conically enlarged towards the main combustion chamber, are also shown in the specification.—*January* 16, 1957.

## NOISE SUPPRESSION

**766,986.** July 25, 1952.—NOISE SUPPRESSING NOZZLES FOR AIRCRAFT JET PROPULSION ENGINES, Geoffrey Michael Lilley and Robert Westley, both of the College of Aeronautics, Cranfield, Bletchley, Buckinghamshire, and Alec David Young, formerly of that address but now of Queen Mary College, Mile End Road, London, E.1.

The invention relates to the suppression of part of the noise from aircraft jet propulsion engines. In Specification No. 766,985, from which the present application is divided, it has been proposed to modify the boundary of an issuing jet in such manner that the mixing region between that jet and the ambient air is increased compared with the corresponding region for a plain nozzle exit, and a number of nozzles of modified design are shown in it. In the drawing the downstream termination of the jet pipe of an aircraft engine is shown. The jet pipe proper *A* has attached to it a corrugated nozzle. The end of the jet pipe is of circular cross section and to it is fitted the upstream end *B* of the separately fabricated nozzle. This nozzle is formed with a longitudinally corrugated periphery, the corrugations of which continuously deepen in the downstream direction up to the nozzle exit plane. The circumferential crests *C* of the corrugations are inclined away from the jet axis whilst the walls *D* forming the bases of the corrugations are inclined towards that axis. The total depth of a corrugation at the downstream end of the nozzle is of the same order as the radius of the jet pipe and of the upstream end of the nozzle. The central area of the jet remains unobstructed and



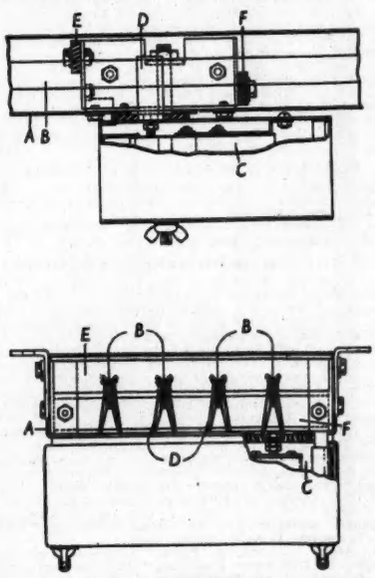

No. 766,986

the jet, therefore, acquires a cross sectional shape which changes gradually in the downstream axial direction and which has a central core *E* with regularly spaced projections *F* around it. This symmetrical petaloid or star-shaped jet issues into the atmosphere and as it does so it contacts the ambient air all along its periphery. The deepening spaces between the walls *D* and the sides *G* of the corrugations are available as external troughs *H* through which the surrounding air may flow. As it flows towards the nozzle exit, the air acquires a peripheral shape complementary to that of the jet. When the two first come into contact, therefore, they do so along an extended peripheral length and intimate mixing is effected. The length of the nozzle is of the same order as the jet pipe diameter. It is found that such configuration provides a satisfactorily effective method of noise suppression of an aircraft jet engine.—*January* 30, 1957.

## ELECTRICAL ENGINEERING

**766,893.** April 12, 1954.—BUSBAR TRUNKING, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2; and John Tierney Martin, of the same address.

Referring to the drawing, the electrical busbar trunking comprises a sheet of rectangular section steel trunking *A* and, supported within the trunking, four spaced bare conductors *B* of flat strip form arranged on edge and side by side parallel to one another. The conductors are supported at spaced points along the trunking by upper and lower notched insulating strips. The trunking is arranged for use with one or more tap-off boxes *C*, including contact fingers which engage the respective conductors *B* and in order that the contact fingers *D* shall correctly engage the conductors at a tap-off point the positions of the conductors are correctly defined by what may



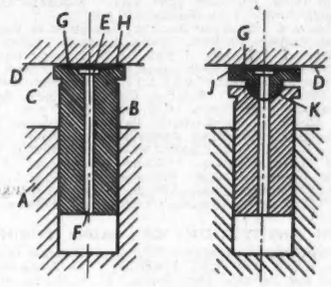

No. 766,893

be termed a split barrier. Thus, instead of placing two insulating and notched strips one above and one below the conductors at a particular point, one strip *E* is placed above the conductors on one side of the tap-off point and the other strip *F* is placed below the conductors on the other side, the spacing between the two strips being kept to a minimum just sufficient to allow a clearance for the contact fingers *D* of the tap-off box *C*. Since the conductors *B* are located accurately on each side of the position where they are engaged by the contact fingers there is no chance of bowing of the conductors causing difficulty in engaging the contact fingers.—*January* 30, 1957.

## PUMPS

**764,698.** February 25, 1954.—PISTON PUMPS OR MOTORS, Ruben Hadekel, 36, Evelyn Gardens, London, S.W.7.

Referring to the left-hand view, a pump according to the invention comprises a cylinder block *A*, formed with one or more bores which are adapted to receive sliding pistons, one of which is shown at *B*. The piston has a flat head *C* which is capable of sliding on a flat track *D*. An eccentric mechanism creates relative motion between the track and the cylinder block. An object of the invention is to provide necessary lubrication in a novel manner. It will be seen that the piston head *C* is formed with a relatively deep recess *E* which communicates with the cylinder through a drilled passage *F*. Outside the recess there is a further and very shallow recess *G*, the depth of which may, for instance, be no more than 0·0002in. The pressure in the recess *E* is substantially equal to

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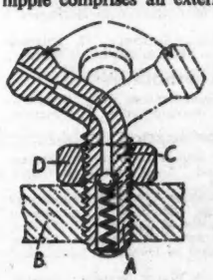
the pressure in the cylinder. From this recess, the fluid pumped leaks out over the surface of the shallow recess *G* and over the surface *H* of the piston head, and under working conditions pressure drops gradually from the value obtaining in recess *E* to that in the pump casing, which is substantially atmospheric. The piston head is thus subject to a force directed inwards towards the cylinder, which is opposed by the force exerted by the full pressure in the cylinder acting on the inner end face of the piston. In the case of pumps designed to operate at high pressures it may be more convenient to adopt the construction shown in the right-hand view. The piston head consists of a separate pad *J* which is articulated on the piston on a spherical seat *K* and is thus free to align its flat outer surface with that of the track *D*. In other respects the construction shown is identical with that already described. The effect of the shallow recess *G* is not only to establish a film of fluid of definite thickness, but also to cause the piston head to maintain a position parallel to the track. Pumps according to the invention are also described in the specification.—*January* 2, 1957.

## LUBRICATING DEVICES

**766,921.** September 8, 1954.—LUBRICANT NIPPLES, Victor Charles Gorman, 104, Pield Heath Road, Hillingdon, Middlesex.

The invention has for its object to provide an improved lubricating nipple which can be easily and quickly adjusted and locked in a position in which the head is readily accessible for engagement by a grease gun. As will be seen from the drawing, the nipple comprises an externally threaded stem *A* of such a length that when it is screwed in a machine part *B* it has a portion *C* which extends beyond the face for receiving a lock nut *D*. The stem has extending from it a lubricant receiving arm provided at its outer end with a nipple head. As shown, the stem is formed with a counter bore accommodating a spring-loaded ball valve seating on a shoulder. It will be appreciated that the nipple can initially be fitted in a position in which the arm projects in a required direction so as to be readily accessible, or alternatively, should circumstances demand, the arm can occupy a position in which it is normally inaccessible to a grease gun but can be moved to an accessible position by slackening the lock nut and then swivelling the nipple to point the arm in the required direction and then temporarily locked in this position by retightening the lock nut.—*January* 30, 1957.

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# Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### ASSOCIATION OF MINING ELECTRICAL AND MECHANICAL ENGINEERS

*Tues., March* 5.—21, Bloomsbury Street, London, W.C.1, "Generation of Electricity by the Utilisation of Methane Gas," R. Shillington, 5.45 p.m.

### ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

*To-day, March* 1.—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, 2, "Trends of Developments of Electric Traction," J. H. Cansdale, 7.30 p.m.

*Mon., March* 4.—CENTRAL LONDON BRANCH: White Hall Hotel, Bloomsbury Square, London, W.C.1, "Cathode Ray Tubes and T.V.," C. H. Gardner, 7.30 p.m. ★ LEEDS BRANCH: Great Northern Hotel, Leeds, "R.F. Heating and its Application in Industry," J. Pound, 7.30 p.m. ★ N.W. LONDON BRANCH: Century Hotel, Forty Avenue, Wembley Park, 1956 Electrical Engineers (A.S.E.E.) Exhibition Film, 8.15 p.m.

*Tues., March* 5.—N.E. LONDON BRANCH: Angel Hotel, Ilford, "The Balu Chaung Hydro-Electric Scheme," J. A. Hill, 7.30 p.m. ★ OXFORD, READING AND DISTRICTS BRANCH: University, London Road, Reading, "The Uses of Electronic Valves," C. H. Gardner, 7.15 p.m. ★ TYNESIDE BRANCH: Crown Hotel, Newcastle upon Tyne, "Industrial Uses of Magnetic Power," T. G. Hawker, 7.30 p.m.

*Wed., March* 6.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "Safety in the Factory," J. W. Jones, 8 p.m. ★ N. LONDON BRANCH: Queen's Head, 677, Green Lanes, Harringay, London, N.4., 1956 Electrical Engineers (A.S.E.E.) Exhibition Film, 7.45 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Thermal Storage Heating," C. J. Wheeler, 7.30 p.m.

*Thurs., March* 7.—SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Earthing and Fault Protection," H. W. Swann, 8 p.m. ★ S. LONDON BRANCH: Halfmoon Hotel, Broad Green, Croydon, "Factory Installations," 8 p.m. ★ S.W. LONDON BRANCH: Prince of Wales Hotel, Hartfield Road, Wimbledon, London, S.W.19, "Industrial Relations"; and 1956 Electrical Engineers (A.S.E.E.) Exhibition Film, 8.30 p.m.

### BRITISH INSTITUTION OF RADIO ENGINEERS

*Wed., March 6th.*—MERSEYSIDE SECTION: Chamber of Commerce, 1, Old Hall Street, Liverpool, "The Preparation of Service and Technical Data Sheets," E. A. W. Spreadbury, 7 p.m.

*Thurs., March* 7.—N.W. SECTION: College of Technology, Sackville Street, Manchester, "Electronic Musical Instruments," A. Douglas, 6.30 p.m.

### BRITISH INTERPLANETARY SOCIETY

*Sat., March* 2.—Caxton Hall, Caxton Street, London, S.W.1, "The Design and Application of Solid Propellant Rocket Motors," E. T. B. Smith, 6 p.m.

### COVENTRY ENGINEERING SOCIETY

*Thurs., March* 7.—Coventry Victor Social Club, Coventry, "Applications of Carbide Tools," 7.30 p.m.

### ILLUMINATING ENGINEERING SOCIETY

*Wed., March* 6.—EDINBURGH CENTRE: Y.M.C.A., 14, South St. Andrew Street, Edinburgh, "Lighting and Production," J. W. Howell, 6.15 p.m. ★ SWANSEA GROUP: S. Wales Electricity Board, Kingsway, Swansea, "Lighting for Photography," R. W. Unwin, 6.30 p.m.

*Thurs., March* 7.—CARDIFF CENTRE: S. Wales Electricity Board, The Hayes, Cardiff, "Lighting for Photography," R. W. Unwin, 7 p.m. ★ GLASGOW CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, "Lighting and Production," J. Howell, 6.30 p.m. ★ NOTTINGHAM CENTRE: Electricity Service Centre, Smithy Row, Nottingham, "Lighting Considered as a Basis for Design," D. Phillips, 5.30 p.m.

### INCORPORATED PLANT ENGINEERS

*Mon., March* 4.—DUNDEE BRANCH: Mathers Hotel, Dundee, Annual General Meeting, followed by an address by Sir Oliver Lyle, 7.30 p.m.

*Tues., March* 5.—EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, Annual General Meeting, 7 p.m.

*Wed., March* 6.—GLASGOW BRANCH: More's Hotel, Glasgow, Annual General Meeting, 7.15 p.m.

*Thurs., March* 7.—PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Development and Operation of Wind Tunnels," D. Grundy, 7.30 p.m.

### INSTITUTE OF MARINE ENGINEERS

*Mon., March* 4.—MERSEYSIDE AND N.W. SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Welding of Steam and Feed Pipework for Marine Installations," J. Chamberlain and W. L. Roe; and "The Influence of Weld Faults on Fatigue Strength, with Reference to Butt Joints in Pipelines," R. P. Newman, 6.30 p.m.

### INSTITUTE OF METALS

*Tues., March* 5.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, "The Writing of Scientific Papers," W. Hume-Rothery, 7 p.m.

*Thurs., March* 7.—LONDON LOCAL SECTION: 17, Belgrave Square, London, S.W.1, "Gas in Light Alloys," C. E. Ransley, 6.30 p.m.

### INSTITUTE OF PETROLEUM

*Wed., March* 6.—26, Portland Place, London, W.1, "Trends in Exploration Methods," H. R. Warman and A. T. Dennison, 5.30 p.m.

### INSTITUTE OF PHYSICS

*Tues., March* 5.—N.E. BRANCH: Science Laboratories, Durham University, South Road, Durham, "Solid State Image Amplifiers," G. F. J. Garlick, 5.30 p.m.

*Wed., March* 6.—SCOTTISH BRANCH: Natural Philosophy Department, Marischal College, Aberdeen, "Research in Nuclear Physics at the University of Glasgow," P. I. Dee, 7.15 p.m. ★ EDUCATION GROUP: 47, Belgrave Square, London, S.W.1, "An Experiment in University Education," F. A. Vick, 6 p.m.

*Fri., March* 8.—LIVERPOOL AND N. WALES BRANCH: Department of Electrical Engineering, University of Liverpool, Brownlow Street, Liverpool, "Pion Physics," J. M. Cassels, 7 p.m. ★ MANCHESTER AND DISTRICT BRANCH: Bragg Building, University of Manchester, "Some Aspects of Vision," R. A. Weale, 6.45 p.m. ★ S. WALES BRANCH: University College of Swansea, Swansea, "The Recording of Faint Optical Images," J. D. McGee, 5.15 p.m.

### INSTITUTE OF REFRIGERATION

*Thurs., March* 7.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Automatic Control Systems for Refrigerating Plant in Air Conditioning," D. H. Powell, 5.30 p.m.

### INSTITUTE OF ROAD TRANSPORT ENGINEERS

*Mon., March* 4.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "The Design and Construction of a Modern Goods-Carrying Vehicle," A. S. C. Marks, 7.30 p.m.

*Tues., March* 5.—E. CENTRE: The Canteen, Eastern Counties Omnibus Company, Ltd., Norwich, "Mechanical Handling," 7 p.m.

*Wed., March* 6.—E. MIDLANDS CENTRE: Mechanics' Institute, Nottingham, "The Development of the Hobbs Transmission Gear," J. Hobbs, 7.30 p.m.

*Thurs., March* 7.—W. CENTRE: Royal Hotel, Bristol, "Wheel Alignment in Relation to Tyre and Vehicle Performance," G. H. I. List, 6.30 p.m.

*Fri., March* 8.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "From the Laboratory to the Road," W. A. Snell, 7 p.m.

### INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

*Tues., March* 5.—W. CENTRE: Lackhan School of Agriculture, Chippenham, "Mechanical Handling and Preparation of Feeding Stuffs on the Farm," J. T. Taylor, 7.15 p.m.

### INSTITUTION OF CHEMICAL ENGINEERS

*Tues., March* 5.—Geological Society, Burlington House, Piccadilly, London, W.1, "The Effect of Sonic Vibrations on Heat Transfer from Town Gas," S. R. Tailby and I. Berkovitch; and "Heat Transfer from Coal Gas Flames to Water Jacketed Horizontal Tubes," S. R. Tailby and M. D. Ashton, 5.30 p.m.

### INSTITUTION OF CIVIL ENGINEERS

*Tues., March* 5.—PUBLIC HEALTH AND B.N.E.C.: Great George Street, Westminster, London, S.W.1, "Behaviour of Radioisotopes in Sewage Treatment and the Disposal of Radioactive Wastes to Sewers," A. W. Kenny, 5.30 p.m.

*Wed., March* 6.—N.W. ASSOCIATION: Hornby Library, Central Libraries, William Brown Street, Liverpool, "The Repair of Fire Damage at Skerryvore Lighthouse," P. H. Hyslop, 7.30 p.m.

*Thurs., March* 7.—N.W. ASSOCIATION: Engineers' Club, 17, Albert Square, Manchester, "Problems Arising in Model Studies of the River Alt Outfall," D. M. Clapp; and "Scale Model Tests Related to Proposed New Works at Stanlow Oil Docks," J. M. Hobbs, 6.30 p.m. ★ HULL AND E. RIDING BRANCH: Electricity Showroom, Ferensway, Hull, "Nuclear Power Station Construction," W. H. C. Pilling, 6.14 p.m.

### INSTITUTION OF ELECTRICAL ENGINEERS

*To-day, March* 1.—S. CENTRE: South Dorset Technical College, Weymouth, "Analogue Computers," R. Postlethwaite, 6.30 p.m.

*Mon., March* 4.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2. Informal Evening, "Electronics in Administration—a Survey," D. C. Espley, 5.30 p.m. ★ S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Post Office Telephone Network," A. Ness; "Electricity in Ships," J. E. Herrin; and "The Use of Aluminium for Busbars," A. Davies, 6 p.m. ★ MERSEY AND N. WALES CENTRE: Liverpool Royal Institution, Colquitt Street, Liverpool, "Some Industrial Applications," H. A. Thomas, 6.30 p.m. ★ E. ANGLIAN SUB-CENTRE: Crown and Anchor Hotel, Ipswich, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 6 p.m. ★ N.E. RADIO AND MEASUREMENTS GROUP: King's College, Newcastle upon Tyne, "An Experimental Study of High-Permeability Nickel-Iron Alloys," C. E. Richards, E. V. Walker and A. C. Lynch, 6.15 p.m. ★ MAIDSTONE DISTRICT MEETING: Medway College of Technology, Maidstone Road, Chatham, "A Description of a Medium-Sized Electrical Distribution System," R. W. Robinson, 6.30 p.m.

*Tues., March* 5.—S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "Earth Loop Resistance Measurements," G. F. Tagg, 7 p.m. ★ E. MIDLAND CENTRE: E.M.E.B. Service Centre, Derby, "Electrolytic Processes for Surface Conditioning of Metals," J. W. Cuthbertson, 6.30 p.m. ★ E. ANGLIAN SUB-CENTRE: Cavendish Laboratory, Cambridge, "Cathodic Protection," L. B. Hobgen, K. A. Spencer, and P. W. Heselgrave, 8 p.m. ★ N. MIDLAND CENTRE: Town Hall, Barnsley, "Mine Locomotives," T. E. Green, 7 p.m. ★ N.W. CENTRE: Engineers' Club, 17, Albert Square, Manchester, "D.C. Winder Drives Using Mercury Arc Rectifier/Inverters," L. Abram, J. B. McBreen and J. Sherlock, 6.15 p.m. ★ N. IRELAND CENTRE: Sir William Whittle Hall, Queen's University, Belfast, "Nuclear Energy in the Service of Man," T. E. Allibone, 7.30 p.m.

*Wed., March* 6.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Earth Loop Resistance Measurements," G. F. Tagg, 7 p.m. ★ TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, "Atomic Power Stations," D. F. Welch, 6.30 p.m. ★ S. CENTRE: Central Electricity Authority, 111, High Street, Portsmouth, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Carrick, R. G. Hibberd, and A. J. Blundell, 6.30 p.m.

*Thurs., March* 7.—ORDINARY MEETING: Savoy Place, London, W.C.2. "Cathodic Protection," L. B. Hobgen, K. A. Spencer, and P. W. Heselgrave, 5.30 p.m.

### INSTITUTION OF HIGHWAY ENGINEERS

*To-day, March* 1.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Law and Road Safety," J. J. Leeming, 5.30 p.m.

*Thurs., March* 7.—YORKSHIRE BRANCH: Guildhall, York, "Modern Highway Bridges," P. B. Morice, 7 p.m.

### INSTITUTION OF MECHANICAL ENGINEERS

*To-day, March* 1.—HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Problems in Design of Valves for Liquids," 6.45 p.m. ★ SCOTTISH GRADUATE SECTION: 25, Charlotte Square, Edinburgh, "Manufacture of Transformers," S. A. B. Gray, 7.30 p.m.

*Tues., March* 5.—E. BRANCH: Rhodes House, Oxford, "Does the Emergence of the New Nuclear Energy Industry Invite Changes in the Teaching on Heat Engines?" D. J. Allen-Williams, 7.30 p.m. ★ BIRMINGHAM A.D. CENTRE: George Hotel, Stafford Street, Wolverhampton, "The Free-Piston Engine and its Application," R. W. S. Mitchell, 7 p.m.

*Wed., March* 6.—S. BRANCH: Assembly Rooms, Chichester, Joint Meeting with the Institution of Civil Engineers, "The Construction of the New Woodhead Tunnel," F. A. Sharman, 6.30 p.m. ★ N. IRELAND COMMITTEE: Lecture Room A, Engineering Block, Queen's University, Belfast, "The Salvaging of Ships, with Particular Reference to the 'Empress of Canada,'" W. R. Colbeck, 6.30 p.m. ★ N.E. GRADUATE SECTION: Sunderland Technical College, Sunderland, "Scientific Paradoxes," D. A. Wrangham, 7 p.m.

*Thurs., March* 7.—LIVERPOOL PANEL: Liverpool Engineering Society, 24, Dale Street, Liverpool, "Crankcase Explosions: An Investigation into Some Factors Governing the Selection of Protective Devices," H. G. Freeston, J. D. Roberts, and A. Thomas; and "Crankcase Explosions: Development of New Protective Devices," W. P. Mansfield, 6 p.m. ★ E. MIDLANDS GRADUATE SECTION: Room C4, University of Nottingham, "Engineering in the Brewing Industry," R. J. Rowley, 7.15 p.m.

*Fri., March* 8.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: 1, Birdcage Walk, Westminster, London, S.W.1., Discussion on "Market Research and the Engineer," 6.45 p.m.

### INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

*Tues., March* 5.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Work Study—Its Purpose and Application," R. A. Cooper, 5 p.m.

### INSTITUTION OF PRODUCTION ENGINEERS

*To-day, March* 1.—SOUTHERN BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 7.15 p.m.

*Sat., March* 2.—N.E. GRADUATE SECTION: Visit to Scott Turner, Ltd., Tin Box Factory, Fawdon, Newcastle, 10 a.m.

*Mon., March* 4.—CORNWALL BRANCH: Cornwall Technical College, Trevenson, Pool, Redruth, Cornwall, "Automation," 7 p.m.

*Wed., March* 6.—WOLVERHAMPTON BRANCH: Wolverhampton and Staffs Technical College, Wolverhampton, "Application of Oil Hydraulics to Production Methods," R. G. Hamilton, 6.45 p.m.

*Thurs., March* 7.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, 7.30 p.m. ★ LONDON BRANCH: Telegraph House, East Croydon, Surrey, "Recent Developments in Precision Investment Casting," W. N. Jones, 7 p.m. ★ READING BRANCH: Great Western Hotel, Reading, "Investing in Better Factory Design, Construction and Layout," D. Myers, 7 p.m.

*Fri., March* 8.—E. COUNTIES BRANCH: Britannia Works, Davey, Paxman and Co., Ltd., Colchester, "Trade Unions and Productivity," L. Stubbs, 7 p.m.

### INSTITUTION OF THE RUBBER INDUSTRY

*To-day, March* 1.—SOUTHERN SECTION: Civic Centre, Southampton, Joint Meeting with Royal Institute of Chemistry, "Analysis of Accelerators and Antioxidants," C. A. Parker, 8 p.m.

*Mon., March* 4.—MERSEYSIDE SECTION: Stork Hotel, Liverpool, "Modern Developments in Mould Cleaning," R. Green and W. A. Tandy, 7.15 p.m. ★ N.E. SECTION: Eldon Grill, Grey Street, Newcastle, "Rubber in Ships," 7 p.m.

### INSTITUTION OF STRUCTURAL ENGINEERS

*To-day, March* 1.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Handling of Iron Ore in Steel Works," G. F. Wilson, 6.30 p.m. ★ W. COUNTIES BRANCH: University of Bristol, "Some Practical Aspects of Recent Structural Welding Developments," W. H. Diamond, 6 p.m.

*Tues., March* 5.—N. COUNTIES BRANCH: Cleveland Scientific and Technical Institute, Middlesbrough, "Abbey Steel Works," W. S. Atkins, 6.30 p.m. ★ WALES AND MONMOUTHSHIRE BRANCH: S. Wales Institute of Engineers, Cardiff, "The Design of Aircraft Hangars," J. M. Burke, 6.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: 11, Upper Belgrave Street, London, S.W.1, "Building in Timber," 6.30 p.m.

*Wed., March* 6.—N. COUNTIES BRANCH: Neville Hall, Newcastle upon Tyne, "Abbey Steel Works," W. S. Atkins, 6.30 p.m.

*Thurs., March* 7.—YORKSHIRE BRANCH: Electricity Building, Hull, "Nuclear Power Station Construction," W. H. C. Piling, 6.15 p.m.

### JUNIOR INSTITUTION OF ENGINEERS

*To-day, March* 1.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, 7 p.m.

*Wed., March* 6.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Fuel Economy and Heat-Electric Generation," Bryan Donkin, 7 p.m.

*Fri., March* 8.—ORDINARY MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Treatment of Effluents," A. H. Waddington, 7 p.m.

### LIVERPOOL METALLURGICAL SOCIETY

*Sat., March* 2.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Conversazione," 7 p.m.

### REINFORCED CONCRETE ASSOCIATION

*Tues., March* 5.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "The Design and Construction of Two Dock Sheds at Huskisson Dock, Liverpool," A. T. Clarke, 6.45 p.m. ★ MIDLAND COUNTIES BRANCH: Birmingham and Midland Institute, Paradise Street, Birmingham, "The Manufacture of Hollow Reinforced Concrete Beams," W. C. Roberts, 6 p.m.

*Wed., March* 6.—N.W. BRANCH: Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "The Design and Construction of Two Dock Sheds at Huskisson Dock, Liverpool," A. T. Clarke, 6.30 p.m.

### ROYAL AERONAUTICAL SOCIETY

*Thurs., March* 7.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "New Methods in Aircraft Production," Paul Badre, 6 p.m.

### ROYAL INSTITUTION OF CHARTERED SURVEYORS

*Mon., March* 4.—ORDINARY MEETING: 12, Great George Street, Westminster, London, S.W.1, "The Definition and Designation of Land in Development Plans," J. Kegie, 5.45 p.m.

### ROYAL SOCIETY OF ARTS

*Mon., March* 4.—CANTOR LECTURE: John Adam Street, Adelphi, London, W.C.2, "Lighting in Decoration and Architecture," D. W. Durrant, 6 p.m.

### SOCIETY OF ENGINEERS

*Mon., March* 4.—ORDINARY MEETING: Geological Society, Burlington House, Piccadilly, London, W.1, "Airships and Balloons," Rt. Hon. Lord Ventry, 5.30 p.m.

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# Advanced Engineering Courses

**Principles of Automation.** THE COLLEGE OF TECHNOLOGY, Brunel House, Ashley Down, Bristol, 7. Course of five lectures commencing March 15. Fridays at 7 p.m. Fee £1 1s.

**The Statistical Design of Multilevel Experiments.** THE COLLEGE OF TECHNOLOGY, Brunel House, Ashley Down, Bristol, 7. Course of seven lectures, commencing April 5. Fridays at 7 p.m. Fee £2 2s.

**Nuclear Metallurgy.** BATTERSEA POLYTECHNIC, Battersea Park Road, London, S.W.11. Tuesday to Friday, April 9 to 12 (inclusive), 10 a.m. to 5.15 p.m. Fee £10 10s.

**The Treatment of Trade-Waste Waters and The Prevention of River Pollution.** DEPARTMENT OF CIVIL ENGINEERING, PUBLIC HEALTH ENGINEERING SECTION, King's College, University of Durham. Monday to Friday, April 1 to 12. (inclusive). Fee £18.

**Basic Principles of Nuclear Engineering.** THE UNIVERSITY, LIVERPOOL. Course of sixteen lectures with demonstrations and discussions. Sunday to Saturday, April 7 to 13. Fee £15 15s. (non-residential £10 10s.).

**Tensor Analysis Applied to Electrical Engineering.** THE UNIVERSITY, LIVERPOOL. Sunday to Friday, April 7 to 12. Fee £12 12s. (non-residential £7 10s.).